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U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Enforcement
Office of General Enforcement
Washington, D.C. 20460

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This manual provides technical information to assist enforcement personnel at both state and federal levels in initiating actions to effect compliance by municipal incinerators with State Implementation Plan requirements. In addition to information pertaining to size, process, control equipment, and probable compliance status of the 108 municipal incinerators currently operating within the 48 contiguous states, this manual lists the appropriate emission limitations for each state and discusses methods of incinerating municipal waste and controlling the consequent air pollution.

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ENFORCEMENT MANUAL

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Enforcement
Office of General Enforcement
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January 1977

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1.0 INTRODUCTION

The total quantity of municipal solid waste generated in the United States has been estimated at 5.5 pounds per capita per day.(1) This must, by one means or another, be disposed of. While there are several solid waste disposal and reduction methods currently in practice, incineration is an approach which minimizes refuse volume, destroys the bulk of noxious odors and putrescible substances while maintaining maximum effective use of available and scarce land near to the population centers which require its use.

Incineration is a combustion process, and like all combustion processes, it is a source of smoke, particulate matter, and a wide variety of gaseous contaminants. Studies(2) have shown that approximately 8% of the refuse collected in the United States is subjected to incineration and that this percentage has remained relatively constant over the last 10 years. Today there are 108 municipal incinerators whose capacity is in excess of 50 tons per day operating in the U.S. Emissions from most of these units are uncontrolled or at best only partially controlled. In fact, if all existing municipal incinerators were to just meet applicable local, state, and federal regulations, particulate emissions from these facilities would be reduced by an overall 86%.(2)

Nationwide, the compliance record of municipal incinerators with state and local regulations is perhaps the worst of any major stationary source category. As of July 1976, 75 out of 108 municipal incinerator installations in the U.S. were not in compliance with appropriate regulations. Of these 75, 23 were not even on a compliance schedule. Since incinerators are generally located as a function of population density, the impact of their emissions on public health and welfare is significant.

Clearly, the control of pollutant emissions from this source category is a problem with which environmental regulatory officials must reckon. Accordingly, this Manual has been prepared to assist enforcement personnel on both state and federal levels in initiating actions to effect compliance with State Implementation Plan (SIP) requirements. The purpose of the Manual is four fold:

- Supply to enforcement personnel a ready reference as to the compliance status of each municipal incinerator within their jurisdiction.
- Develop the basis for making field judgments regarding the effectiveness of present air pollution controls extrapolating findings to other similar units.
- Provide up-to-date information on the latest control device technology, costs, vendors and design/delivery schedules.
- Suggest an effective and reasonable compliance schedule for implementation by the incinerator owner.

This Manual is applicable to:

- Incinerators with a capacity in excess of 50 tons per day of refuse burning capability.
- Incinerators designed specifically for and limited to the handling of residential and commercial paper, cardboard, garbage, and yard wastes.
- Incinerator installations within the 48 contiguous states.

2.0 COMPLIANCE STATUS

2.1 Statistics

Since 1920, 322 municipal incinerators have been built in the United States with a total installed design capacity of nearly 100,000 tons per day. However, in 1969 only 251 incinerators with an aggregate design capacity of 80,000 tons per day were actually operating. An inventory conducted by the Office of Solid Waste Management Programs (OSWMP)(3) showed that as of May 1972 only 193, with a daily design capacity of 71,000 tons, were operating. As of June 1976, the number had been further reduced to 108 with a total daily design capacity of approximately 43000 tons.

During the period 1945 to 1967, an average of over 13 separate increases in installed design capacity took place each year, but fewer than four per year have occurred since 1967. Possible reasons for the decline in construction and in the increased closing of old incinerators are:

- Many municipalities presently have sufficient incinerator capacity.
- The high costs associated with upgrading existing incinerators to control air pollutant emissions are forcing municipalities to opt for less expensive sanitary land fill operations.
- Municipalities requiring additional processing capacity are putting off construction plans due to high capital and operating costs and are overburdening their present units.

The decline in utilization of municipal incinerators may be accelerated further if political jurisdictions at various levels continue to set standards more stringent than those of the Federal Government. Federal standards for new or modified units are established at a level that the best available technology can achieve with reasonable costs. In addition, resource recovery systems and new systems for thermal processing of solid wastes such as pyrolysis, gasification, vortex incinerators, and utility boilers which can process solid wastes are being developed. Communities which require processing to achieve volume reduction in the future may utilize these new systems instead of conventional municipal incinerators.

Of the 108 municipal incinerators currently operating in the United States, 33 are in compliance with their appropriate state or local air pollution control regulations. Of the remaining 75 operational units, 45 are on compliance schedules, 23 are not on compliance schedules, and 7 have schedules pending. Included in the list of 108 incinerators are 7 which were built after December 23, 1971. Emissions from these facilities are regulated by New Source Performance Standards (NSPS). A total of 197 additional municipal incinerators have been shut down and are no longer operational. More than half of these were closed since 1970, indicating the effect of major environmental legislation.

2.2 Compliance Profile

Table 2-1 lists all the municipal incinerators currently operating within the 48 contiguous states. Information pertaining to size, process, pollution control equipment and compliance status is also summarized for each unit. The listing is organized in terms of the ten EPA regions and subcategorized for each state within the region to facilitate use of this Manual by both state and federal officials. As new, or more up-to-date information becomes available, Table 2-1 may be updated. Sources which are subject to NSPS are included in the Table and are denoted by an asterisk.

TABLE 2-1

OPERATING MUNICIPAL INCINERATORS (2)
IN THE UNITED STATES

EPA Reg.	State	Incinerator Name	Address	Size-TPD		Process Description			Pollution Control Equipment		Compliance				Compliance Date	Comments and Complying Actions
											Status		Schedule			
				Design	Operational	Type	Grate	Furnace	Type	Efficiency (%)[1]	In	Out	Yes	No		
I	MA	*Reading	195 John St	144	50	C	RK		ESP	95	✓					
		Holyoke	Berkshire St	225	58	B	MA		DSC	(10)		✓	✓		8/76	Shutdown
		Framingham	Mt Waite Ave	200	83	C	T		WSC,SCR	40		✓		✓		
		Winchester	Swanton St	100	67	B	RK		WSC,C	90		✓	✓		8/76	Shutdown
		*Braintree	Ivery St	240	240	C	T		ESP	99.9	✓					Closed 5/76 to re-open summer 76
		*E. Bridgewater	E. Bridgewater	300	300	C	T		FF	(95)	✓					
		Marlboro	Marlboro			C			SCR	(80)		✓		✓		
	NH	Manchester	Maple St	125	103	B	MA				✓					
		Durham	Durham Point Rd		50	C	-		SCR	(80)	✓					
	RI	Pawtucket	Grotto Ave	400	115	C	T		SCR	60		✓	✓		1/75	Not meeting Schedule
	CT	Ansonia	N. Division St	200	150	C	RK		WSC	60		✓		✓		Testing
		City of Bridgeport	Asylum St	200	160	B	RK		WSC	35		✓	✓		2/1/77	Shutdown
		Bridgeport	Bostwick Ave	300	250	P	CI		WSC	35		✓	✓		2/1/77	Shutdown
		E. Hartford(old)	141 Ecology Dr	200	150	B	RK		WSC,DSC	75		✓	✓		10/1/76	Shutdown
		E. Hartford(new)	141 Ecology Dr	288	150	C	T		WSC	50		✓	✓		10/1/76	Shutdown
		Greenwich(old)	Town Hall Annex	150	125	B	RK		DSC	15		✓	✓		2/1/77	Shutdown
		Greenwich(new)	Town Hall Annex	250	150	C	RK		WSC	35		✓	✓		2/1/77	Shutdown
		New Canaan	Main St	144	100	C	ME		SCR	80	✓					
		New Haven	260 Middletown Ave	720	600	C	T		WSC	35		✓	Pending			
		New London	100 Trumbull St	120	60	B	RK		DSC	15		✓	✓		3/1/77	Shutdown
		Norwalk	West Ave	360	160	C	T		WSC,SCR	95	✓					
		Stamford	Harborview Ave	210	160	C	-		ESP	90		✓	✓		12/1/76	Shutdown to Upgrade
		Stamford	Harborview Ave	360	156	C	-		ESP	90	✓					
		Stratford	Town Hall	240	110	C	T		WSC	35		✓	✓		2/1/77	Shutdown
		Waterbury	City Hall	300	250	B	CI		WSC	35		✓	✓		10/1/76	Shutdown
		West Hartford	28 South Main St	350	200	B	CI		WSC	(20)		✓	✓		10/1/76	Shutdown
II	NY	Mt Vernon	Mt Vernon	600		B	CI,ME		-	-		✓		✓		
		Babylon #1	Gleam St, Babylon	300	300	B	CI,ME		WSC	([illegible]0)	✓					
		Beacon	Beacon	100	33	B	RK		WSC	(20)		✓		✓		
		Buffalo	Buffalo	600	575	B	CI,ME		WSC	(20)		✓	✓			Not meeting Schedule
		East Chester	East Chester	200	67	B	RK		WSC	(20)		✓	✓		1/78	This is new proposed shutdown date
		Freeport	Freeport	150	100	B	RK		WSC	(20)		✓	✓		1978	Shutdown
		Garden City	Garden City	175		C	R		WSC	(20)		✓	✓		1978	Shutdown
		Islip #1,#2	Islip	300		C	T		None	-		✓		✓		
		Merrick	Merrick, Hempstead	700	500	B	CI,ME		ESP	(90)	✓					
		Oceanside	Oceanside, Hempstead	750	200	C	RK		WSC	(20)		✓	✓		1978	
		New Hyde Park	N. Hempstead	250	190	B	CI,ME		SCR	(80)		✓	✓		1977	Shutdown
		Roslyn Harbor	Roslyn Harbor	600	495	-	RK,T		C	(30)		✓		✓		
		Huntington #1	Huntington	150	150	C	RK		DSC,SCR	(90)	✓					
		Huntington #2	Huntington	150	150	-	-			-	✓					
		Long Beach	Long Beach	200		B	CI,ME		WSC	(20)		✓	✓		1978	Shutdown
		New Rochelle	New Rochelle	400	240	-	-		WSC	(20)		✓	✓		1980	This is new proposed shutdown date
		Oyster Bay #1	Oyster Bay (Bethpage)	500	285	B	-		WSC	(20)		✓		✓		
		Oyster Bay #2	Oyster Bay	500	333	C	RK		WSC	(20)	✓					
		Rye	Rye	240	46	B	CI,ME		WSC	(20)		✓	✓		1/78	This is new proposed shutdown date
		Scarsdale	Scarsdale	150		B	CI,ME		WSC	(20)		✓	✓		1/78	This is new proposed shutdown date
		Tonawanda #1	Tonawanda	100	30	-	RK		DSC	(10)	✓					
		Tonawanda #2	Tonawanda	250	115	-	-		WSC	(20)	✓					
		Valley Stream	Valley Stream	200		C	T		WSC	(20)		✓	✓		1978	Shutdown

*Sources subject to New Source Performance Standards (NSPS)

(1) Values in parentheses are estimated efficiencies

(2) As of 6/15/76

TABLE 2-1 (CONTINUED)

OPERATING MUNICIPAL INCINERATORS(2)
IN THE UNITED STATES

EPA Reg.	State	Incinerator Name	Address	Size-TPD		Process Description			Pollution Control Equipment		Compliance				Compliance Date	Comments and Complying Actions
											Status		Schedule			
				Design	Operational	Type	Grate	Furnace	Type	Efficiency (%)[1]	In	Out	Yes	No		
		White Plains	White Plains	400	180	B	RK		WSC	(20)		✓	✓		1980	This is new proposed shutdown date
		Yonkers	Yonkers	560	480	B	CI,MR		WSC	(20)		✓	✓		1/78	This is new proposed shutdown date
		Gansevoort	New York City	1000		C	T		DSC,WSC	(30)		✓	✓		1977	Will Shutdown
		South Shore	Brooklyn	1000	660	C	T		DSC,FF	(95)		✓		✓		
		Greenpoint	Brooklyn	1000	750	C	T		None	-		✓	✓		1976	Upgrade with ESP
		Hamilton Ave	Brooklyn	1000	750	C	T		WSC,DSC	(30)		✓		✓		
		SW Brooklyn	Brooklyn	1000	750	C	T		WSC	(20)		✓	✓		1976	Upgrade with ESP
		Betts Ave	Queens	1000	620	C	T		DSC,FF	(95)		✓		✓		
III	PA	Ambridge	1001 Merchant St	150	35	-	RK		-	-		✓		✓		Court Action
		Bradford	Bradford	200	119	P	RK		SCR	65		✓		✓		
		Delaware Co.#1	Feltonville	500	330	C	T		SC	70		✓	✓		1977	
		Delaware Co.#2	Folcroft	500	124	C	T		SC			✓	✓		1978	
		Delaware Co.#3	Broomall	500	320	C	T		LSCR	85		✓	✓		1978	
		Lower Merion	1300 Woodbine	250	226	C	RK		LSCR	85		✓		✓		
		NW Philadelphia	Domino and Umbria St	600	585	C	T		C	(30)	✓					
		E. Cent. Philadelphia	Del and SP Garden St	600	570	C	T		LSCR	50		✓	✓		1975	Will be in Compliance Summer 1976
		Red Lion Borough	Red Lion			-	-		-	-	✓					
		White Marsh	White Marsh			-	-		-	-	✓					
	VA	City of Alexandria	Alexandria	300		C	RK		WSC,DSC	(30)		✓		✓		
		Portsmouth	Portsmouth	350		B	-		WSC	(20)	✓					May be standby in 1979
	DC	Benning Rd #5	Washington DC	1200	1000	C	T		ESP,C,WSC	(99)	✓					
	MD	Pulaski #4	Baltimore			-	-		ESP,WSC	(99)	✓					
IV	FA	Port St Joe	Port St Joe	96	39	-	-		SCR	99	✓					
		Ft Lauderdale	1300 N Wingate	450	428	C	R		WSC	(20)		✓		✓		
		Broward Co.#1	Ft Lauderdale	300	300	C	R		SCR	87		✓	✓		9/24/76	Not meeting Schedule
		Broward Co.#2	Pompano Beach	300	300	C	R		SCR	95		✓		✓	9/24/76	Not meeting Schedule
		City Hall-Dinner Key	Miami	900		C		K	SCR	80		✓	Pending			
		Dade County	N. Miami Beach	300		-	R	-	ESP	(90)	✓					
		Tampa	Mckay and Alamo Dr	900	900	C	-	K	SCR	(80)		✓		✓		Being Tested
		*Orlando	McCloud Rd	100		-	-	SA	-	-	✓					
	KY	City of Paris	Stewart St	100		B	R		WSC	(20)	✓					
		Louisville	Clay and Meriwater	1000	850	C	T	K	WSC	(20)	✓					
	TN	*Lewisburg	Lewisburg	60	50	-	-	-	SCR	(95)	✓					Under Construction
		*Nashville Thermal	Nashville	720		C	-	WW	C,SCR	98.5		✓	✓		7/15/76	
V	IL	Calumet	Chicago	1200	1400	B	RK		WSC	(20)		✓	Pending			Will Upgrade
		Chicago NW	Chicago	1600		C	R		ESP	96.8		✓	Pending			Will Upgrade & Shutdown
		Chicago SW	1500 Pershing	1200		C	R	K	WSC	(20)		✓	✓		3/31/77	
		Cicero Incin. Inc.	3815 S. Laramie	720	720	-	-		C	50		✓	Pending			Will Upgrade
	MI	S.E. Oakland Co.	Madison Heights	600	600	C	T		WSC,SCR	(90)	✓					
		Central Wayne Co.	Dearborn Heights	850	450	-	R	-	SCR,WSC	90		✓		✓		Court Suit Pending
		Grosse Pt. Clinton	Grosse Point	600		-	-		-	-		✓	Pending			

*Sources subject to New Source Performance Standards (NSPS)
(1)Values in parentheses are estimated efficiencies
(2)As of 6/15/76

TABLE 2-1 (CONTINUED)

OPERATING MUNICIPAL INCINERATORS(2)
IN THE UNITED STATES

EPA Reg.	State	Incinerator Name	Address	Size-TPD		Process Description			Pollution Control Equipment		Compliance				Compliance Date	Comments and Complying Actions
											Status		Schedule			
				Design	Operational	Type	Grate	Furnace	Type	Efficiency (%)[1]	In	Out	Yes	No		
	WS	City of Sheboygan	507 S. Wildwood	240	227	C	RK		WSC	(20)	✓					
		DePere Ashwaubenon	Leonard St	300	32	B			WSC	(20)		✓		✓		Referred to Att.General
		City of Green Bay	N. Military Ave			B	-		-			✓		✓		Referred to Att.General
		City of Waukesha	900 Sentry Dr		175	C	-		-	-		✓		✓		
	OH	City of Cleveland	3727 Ridge Road	500	244	B	RK		WSC	(20)		✓		✓		
		City of Euclid	27700 Lakeland	200	46	B	RK		WSC	(20)		✓	✓		7/1/75	
		City of Lakewood	12920 Berea Rd	150	165	B	NA		DSC	(10)		✓	✓		9/1/76	
		N. Montgomery Co.	6600 Webster St	600	385	C	T	K	SCR	87		✓	✓		4/1/78	Modif. to Resource Recovery
		S. Montgomery Co.	Moraine	600	385	C	T	K	SCR	87		✓	✓		4/1/78	Modif. to Resource Recovery
		Miami County	2200 North Dr	150	115	C	RK		SCR	-		✓	✓		8/1/76	
	IN	East Chicago	East Chicago		125	C	-		SCR	85	✓					
VI	LA	East Side	New Orleans	400		C	-		DSC,C	(40)		✓	✓		12/76	Shutdown
		Algiers	New Orleans	200		C	T		C	(30)		✓	✓		12/76	Shutdown
		Shreveport	Shreveport	250		-	RK		WSC,C	(50)		✓	Pending			
VII	MO	N. St. Louis	N. Grant St	400	560	-	-		SCR,WSC	88	✓					
		S. St. Louis	South First	400	400	-	-		SCR	88	✓					
VIII	UT	Weber County #2, 3	2599 A. Ave Ogden	300	[illegible]	-	-		DSC,SCR	47		✓	✓		5/15/78	
		*Ogden	Ogden	150	150	-	-		ESP	(95)	✓					

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*Sources subject to New Source Performance Standards (NSPS)

(1) Values in parentheses are estimated efficiencies

(2) As of 6/15/76

Of the 108 municipal incinerators operating in the United States, 87 are in the northeastern quarter* (Figure 2-1). Of these, 63 are in the area designated as the "Incinerator Belt" (area enclosed with the dashed line box shown on Figure 2-1). Thus, almost two-thirds of the total number of incinerators in this country are concentrated in only 0.06 percent of the land area where 13 percent of the nation's population live.

A total of 197 municipal incinerators which were once operational have been shut down. Table 2-2 lists these units and the date that each was closed, to the extent that such information was known.

The data presented in Tables 2-1 and 2-2 were obtained from the following sources:

- Compliance Data System (CDS) printout updates.
- A document prepared by Vulcan-Cincinnati, Inc. entitled "Air Pollution Control Compliance Analysis Report on Municipal Incinerators."
- Communications with EPA regional officials.
- Communications with State environmental officials.

Due to the quantity of information presented, abbreviations have been employed where appropriate. A description of these abbreviations is found in Table 2-3.

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*This includes: New Hampshire, Rhode Island, Vermont, Massachusetts, Connecticut, New York, New Jersey, Pennsylvania, Delaware, Maryland, Virginia, Kentucky, Ohio, Indiana, Illinois, Michigan, Minnesota, and Maine.

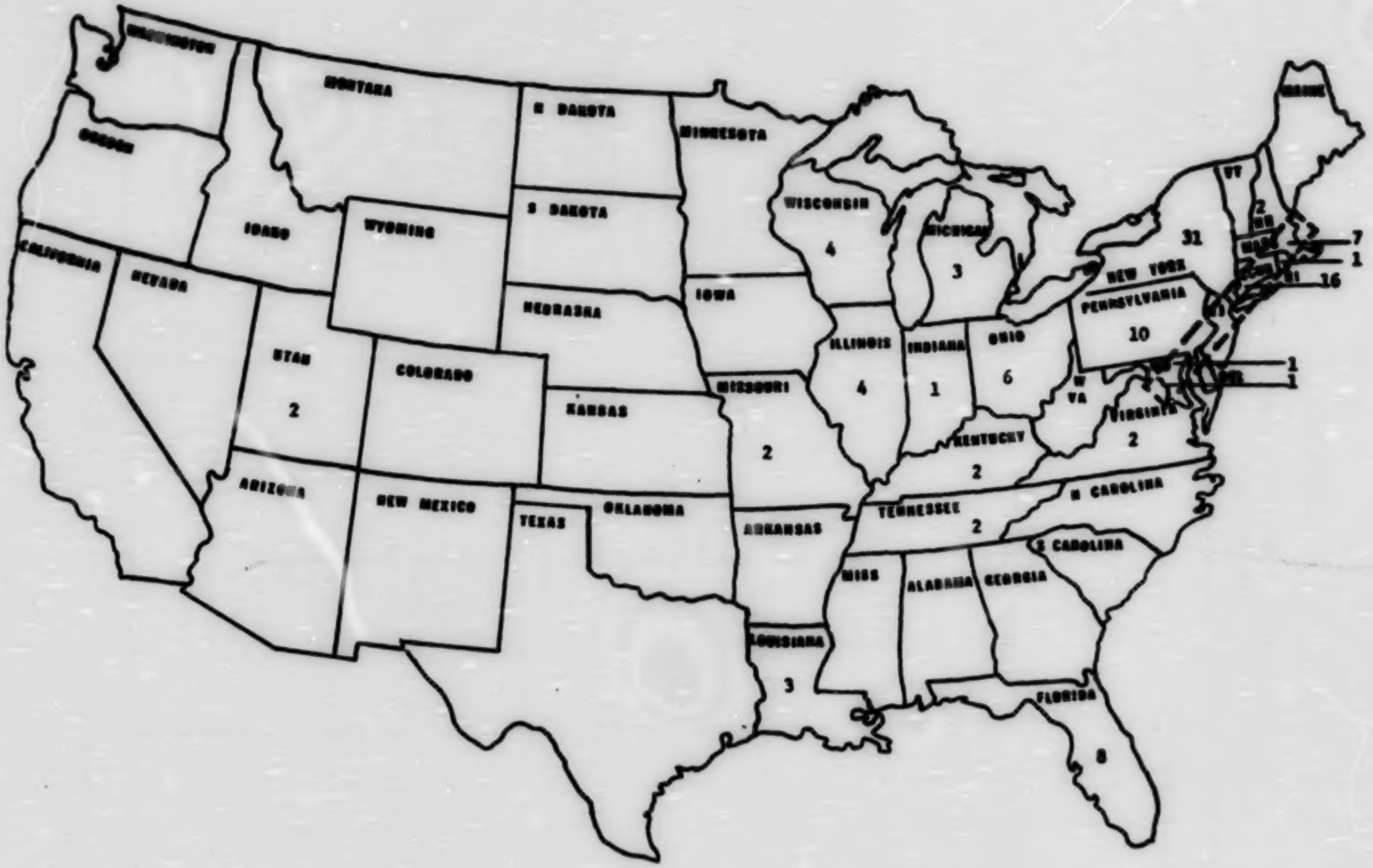
WASHINGTON
MONTANA
N DAKOTA
MINNESOTA
OREGON
IDAHO
WYOMING
S DAKOTA
WISCONSIN
4
MICHIGAN
3
MAINE
VT
2
NH
MASS
7
1
RI
16
31
NEW YORK
PENNSYLVANIA
10
CALIFORNIA
NEVADA
UTAH
2
COLORADO
NEBRASKA
IOWA
ILLINOIS
4
INDIANA
1
OHIO
6
W VA
1
1
KANSAS
MISSOURI
2
KENTUCKY
2
VIRGINIA
2
ARIZONA
NEW MEXICO
TEXAS
OKLAHOMA
ARKANSAS
TENNESSEE
2
N CAROLINA
S CAROLINA
MISS
ALABAMA
GEORGIA
LOUISIANA
3
FLORIDA
8

Figure 2-1

Location of Municipal Incinerators in the United States

TABLE 2-2

CLOSED MUNICIPAL INCINERATORS(1) IN THE UNITED STATES

Region	State	Name	Address	Date Closed
I	CT	Middletown	Middletown	1969
		Middletown	Middletown	1969
		Derby	Derby	1969
		New Britain	New Britain	
		New Milford	New Milford	1969
		West Haven	West Haven	
		Darien (#1,#2,#3)	Darien	1976
		Hartford	70 Incinerator Rd.	1975
	MA	Fall River	Fall River	1969
		Pittsfield	Pittsfield	
		Somerville	Somerville	1974
		Cambridge	90 Bolton St.	1971
		Brookline	815 Newton St.	1975
		Lawrence	Marston St.	1974
		Newton	130 Rumford Ave.	1975
		Worcester	Ballard St.	1973
		Marblehead	Marblehead	1975
		Watertown	Grove St.	1974
		Belmont	1130 Concord St.	1974
		South Bay, Boston	South Bay Ave.	1975
		New Bedford	Shawmut Ave.	1974
		Waltham	165 Lexington St.	1975
		Wellesley	Great Plain Ave.	1975
		Dedham	141 Washington St.	1974
		Salem	Salem	1975
		Lowell	Westford Ave.	1975
		Weymouth	94 Wharf St.	1976
		Fall River	Robeson St.	1976
	RI	Newport	Adam Kalbfus Rd.	~1973
		Providence	Fields Point	~1974
		Providence	Fields Point	
		Providence	Fields Point	
		Warwick	Warwick	
		Woonsocket	Cumberland Hill Rd.	1975
		Newport	Public Works Comm.	

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(1) As of 6/15/76

TABLE 2-2 (CONT.)

CLOSED MUNICIPAL INCINERATORS[1] IN THE UNITED STATES

Region	State	Name	Address	Date Closed
II	NY	Buffalo	Buffalo	1970
		Middletown	Middletown	1968
		Elmira	Elmira	1968
		Schenectady	Schenectady	1967
		Bronx, N.Y.	Bronx, N.Y.	
		Flushing	Flushing	
		Glen Cove	Glen Cove	1969
		Larchmont	Larchmont	1969
		Amsterdam	Amsterdam	
		Babylon	Babylon	1953
		Cheektowaga	Cheektowaga	
		Corning	Corning	
		Troy	Troy	1958
		West Seneca	West Seneca	1961
		Harrison	Harrison	
		Rochester	West Side	
		Binghamton	Binghamton	
		Niagara Falls	Niagara Falls	
		Poughkeepsie	Poughkeepsie	
		Rochester	East Side	
		NYC	74th St.	
		N. Tonawanda	N. Tonawanda	
		Babylon #2	Babylon #2	
		Newburgh	Newburgh	
		Port Chester	Port Chester	1976
	NJ	Hackensack	Hackensack	
		Atlantic City	Atlantic City	1968
		Gloucester City	Gloucester City	1964
		Pennsauken	Pennsauken	
		Woodbridge	Woodbridge	1962
		Jersey City	Jersey City	1974
		Ewing Township	Dover & Stony Ave.	1976
III	PA	Ambridge	Ambridge	
		Bloomsburg	Bloomsburg	1966
		Meadville	Meadville	
		Allentown	Allentown	1972
		Harrowgate	G & Ramona St.	1975
		SE Philadelphia	7th & Pattison	1975
		Bartram	Philadelphia	1975
		NE Philadelphia	Wheatsheat & Delaware	1975
		Abington	Jefferson Ave.	1971

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[1] As of 6/15/76

TABLE 2-2 (CONT.)

CLOSED MUNICIPAL INCINERATORS(1) IN THE UNITED STATES

Region	State	Name	Address	Date Closed
	VA	Staunton	Staunton	
		Arlington County	Court House	1972
		Norfolk	Norfolk	1975
		Alexandria	Alexandria	1973
		Roanoke	Roanoke	~1970
		Norfolk	Norfolk	1972
	D.C.	Fort Totten	Fort Totten	1972
		Georgetown	31 St. O South NW	1971
		Mt. Olivet	1833 W. Va. Ave.	1972
		O St.	1st & O St. SE	1972
	MD	Montgomery County	Montgomery County	1975
		Salisbury	Salisbury	1975
		Reedbird	Reedbird	1975
	WV	Charleston	Charleston	
IV	FL	Jacksonville	Southside	
		Jacksonville	Jacksonville	
		Jacksonville	Jacksonville	
		Hollywood	Hollywood	1973
		Coral Gables	Coral Gables	1968
		Clearwater	Clearwater	
		St. Petersburg	St. Petersburg	
		Orlando	Orlando	
		City of Orlando	800 N. Fairville	~1964
	AL	Bessemer	Bessemer	
	GA	Atlanta	Mayson	1973
		Atlanta	I-285 & Lawrenceville	
		Hartsfield	Hartsfield	1973

(1) As of 6/15/76

TABLE 2-2 (CONT.)

CLOSED MUNICIPAL INCINERATORS(1) IN THE UNITED STATES

Region	State	Name	Address	Date Closed
	KY	Lexington	Lexington	1973
		Lexington	Lexington	1973
		Winchester	Winchester	1972
		Frankfort	Frankfort	1974
V	MI	Ecorse	Ecorse	1968
		Hamtramck	Hamtramck	1966
		Hamtramck	Hamtramck	1971
		Detroit	24th St.	1970
		NW Detroit	NW Detroit	1970
		Trenton	Trenton	1970
		River Rouge	River Rouge	1975
		Detroit	St. Jean	1971 & 1976
		Detroit	Central	1971
	OH	Cincinnati	Red Bank	1969
		Cleveland	Cleveland	1969
		Sidney	Sidney	1969
		E. Cleveland	E. Cleveland	1963
		Columbus	Columbus	1969
		Lima	Lima	1969
		Warren	Warren	1967
		Rocky River	Rocky River	1969
		S. Euclid	S. Euclid	1969
		Bedford	Bedford	1969
		Maple Heights	Maple Heights	1967
		Rocky River	Rocky River	1969
		Dayton	Dayton	~1968
		Cleveland Heights	Cleveland Heights	~1966
		Parma	5311 W. 130th St.	1976
		Dunbar	Cincinnati	1973
		Barberton	Barberton	~1970
		Youngstown	320 Cedar	~1970
		Sharonville	Cincinnati	1974
		Norwood	Cincinnati	~1970
		West Fork	Cincinnati	1975
		Center Hill	5500 Center Hill	1976
		Cheviot	Cincinnati	1976
	MN	St. Louis Park	St. Louis Park	1969
		Minneapolis	Minneapolis	~1970
		Minneapolis	Minneapolis	~1970

(1) As of 6/15/76

TABLE 2-2 (CONT.)

CLOSED MUNICIPAL INCINERATORS[1] IN THE UNITED STATES

Region	State	Name	Address	Date Closed
V	WS	Kenosha	Kenosha	1969
		Kenosha	Kenosha	1969
		West Bend	West Bend	1969
		Port Washington	306 North Park	1976
		Neenah-Menasha	Garfield Ave.	1975
		Oshkosh	639 Dempsey Trail	1975
		Kewaskum	Kewaskum	1973
		Wauwotosa	Wauwotosa	1973
		Racine	Racine	1973
		Racine	Racine	1971
		Racine	Racine	
		Racine	Racine	1971
		Oshkosh	Oshkosh	
		Milwaukee	Milwaukee	1971
		Fond Du Lac	Fond Du Lac	1961
		Green Bay	Green Bay	1973
		Green Bay	Green Bay	1974
		Monroe	Monroe	1973
		Monroe	Monroe	1973
		Merrill	Merrill	1968
		Milwaukee	Milaukee	1971
		West Allis	West Allis	1972
		Whitefish Bay	Whitefish Bay	1972
		Shorewood	Shorewood	1972
		Nekoosa	Nekoosa	1972
	IN	Indianapolis	Indianapolis	1967
		New Albany	New Albany	1962
		Bloomington	Bloomington	1970
	IL	Rosemont	Rosemont	
		Aurora	Aurora	
		Skokie	Skokie	
		Chicago	Chicago	
		Evanston	Evanston	
		Melrose Park	Melrose Park	
		Shiller Park	Shiller Park	

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[1] As of 6/15/76

TABLE 2-2 (CONT.)

CLOSED MUNICIPAL INCINERATORS[1] IN THE UNITED STATES

Region	State	Name	Address	Date Closed
VI	TX	Fort Worth	Fort Worth	
		Fort Worth	Fort Worth	
		Fort Worth	Fort Worth	
		Houston	Paterson	
		Houston	Velasco St.	
		Houston	Holmes Rd.	1975
		Amarillo		
	LA	Gretna	Gretna	~ 1970
		Jefferson Parish	Jefferson Parish	~ 1970
		Jefferson Parish	Jefferson Parish	~ 1970
		New Orleans	7th St.	1976
		New Orleans	Florida Ave.	1976
		New Orleans	St. Louis St.	1976
VII	NE	Omaha	Omaha	1970
IX	CA	Beverly Hills	Beverly Hills	1956
		Pomona	Pomona	1955
		Glendale	Glendale	
		Santa Monica	Santa Monica	
		Los Angeles	Gaffey St.	
		Los Angeles	Lacy St.	

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[1] As of 6/15/76

POLLUTION CONTROL EQUIPMENT

Settling Chamber - SC
  Wet - WSC
  Dry - DSC

Cyclone - C

Scrubber - SCR
  Low Energy - LSCR
  High Energy - HSCR

Electrostatic Precipitator - ESP

Fabric Filter - FF

PROCESS/MECHANICAL CONFIGURATION

B - Batch
C - Continuous

Grate

T - Traveling Grates
R - Reciprocating Grates
RK - Rocking Grates
CI - Circular Grates
MA - Manual Stoking
ME - Mechanical Stoking

Furnace

K - Kiln
SA - Starved Air
WW - Water Wall

Table 2-3
List of Abbreviations

2.3 Emission Limitations

There are eleven sets of units which are presently utilized to define particulate emission limitations from municipal incinerators in the United States. There is also a twelfth, pounds per ton of refuse charged, which is quite popular although it is not used as a legal standard. All twelve sets of units are listed in the table below:

1. gr/scf at 12% CO_2
2. lb/100 lb. dry refuse charged
3. lb/hr
4. gr/scf
5. lb/1000 lb. gas at 50% excess air
6. lb/hr per lb/hr charge
7. lb/1000 lb. gas
8. gr/scf at 7% O_2
9. gr/scf at 50% excess air
10. lb/10^6 btu
11. lb/1000 lb. gas at 12% CO_2
12. lb/ton fuel charged

A complete listing of all the state regulations for particulate emissions for incinerators is presented in Table 2-4. In order to permit the comparison of regulations on a nationwide basis, the actual value of each regulation has been converted to a common set of units - grains per standard cubic foot of flue gas corrected to 12% CO_2. This set of units was chosen because it appears to have the most widespread use and because the New Source Performance Standard for municipal incinerators incorporates these units. The conversion calculations from the specified regulation to the gr/scf @ 12% CO_2 equivalent were accomplished using the following conversion factors:*

1 gr/scf @ 12% = 1.68 lbs/1000 lbs flue gas at 50% excess air

= 1.89 lbs/1000 lbs flue gas at 12% CO_2

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*Based on refuse of 4,450 btu/lb. HHV

TABLE 2-4

EMISSION LIMITATIONS FOR EXISTING MUNICIPAL INCINERATORS

State	Regulation				Equivalent Common Regulation gr/scf@12%CO_2
	Value	Units	Corrected To	Process Conditions	
AL	.1	lbs/100 lbs charged		>50 TPD	.11
	.2	lbs/100 lbs charged		All Others	.21
AK	.3	gr/scf	12% CO_2	≤200 lbs/hr	.3
	.2	gr/scf	12% CO_2	200-1000 lbs/hr	.2
	.1	gr/scf	12% CO_2	>1000 lbs/hr	.1
AZ	.17	lbs/1000 lbs gas	12% CO_2		.09
AR	.2	gr/scf	12% CO_2	≥200 lbs/hr	.2
	.3	gr/scf	12% CO_2	<200 lbs/hr	.3
CA	.3	gr/scf	12% CO_2	Typical of all 43 APCD's	.3
CO	.1	gr/scf	12% CO_2	New	.1
	.15	gr/scf	12% CO_2	Existing	.15
CT	.08	gr/scf	12% CO_2	New	.08
	.4	lbs/1000 lbs	50% excess air	Existing	.24
DE	2.0	lbs/hr		1000 lb/hr	.21
	5.0			>3000 lb/hr	.021
FL	.08	gr/scf	50% excess air	≥50 TPD (new)	.09
	.1	gr/scf	50% excess air	≥50 TPD (existing)	.11
GA	.08	gr/scf	12% CO_2	>50 TPD	.08
	.1	gr/scf	12% CO_2	≤50 TPD	.1
	.2	gr/scf	12% CO_2	Existing before 1/1/72	.2
ID	0.2	lbs/100 lbs charged			.21
IL	.08	gr/scf	12% CO_2	>2000 lbs/hr	.08
	.02	gr/scf	12% CO_2	≤2000 lbs/hr (existing)	.02
	.05	gr/scf	12% CO_2	>60,000 lbs/hr	.05
	.1	gr/scf	12% CO_2	≤2000 lbs/hr (new)	.1

TABLE 2-4 (CONTD.)

EMISSION LIMITATIONS FOR EXISTING MUNICIPAL INCINERATORS

State	Regulation				Equivalent Common Regulation gr/scf@12%CO_2
	Value	Units	Corrected To	Process Conditions	
IN	.4	lbs/1000 lbs gas	50% excess air	>1000 lbs/hr	.24
	.7	lbs/1000 lbs gas	50% excess air	All others	.42
IA	.2	gr/scf	12% CO_2	≥1000 lbs/hr	.2
	.35	gr/scf	12% CO_2	<1000 lbs/hr	.35
KS	.3	gr/scf	12% CO_2	<200 lbs/hr	.3
	.2	gr/scf	12% CO_2	200-20,000 lbs/hr	.2
	.1	gr/scf	12% CO_2	>20,000 lbs/hr	.1
KY	.2	gr/scf	12% CO_2	>50 TPD	.2
	.08	gr/scf	12% CO_2	≤50 TPD	.08
LA	.2	gr/scf	12% CO_2		.2
ME	.2	gr/scf	12% CO_2	≤50 TPD	.2
MD	.03	gr/scf	12% CO_2		.03
MA	.1	gr/scf	12% CO_2		.1
MI	.3	lbs/1000 lbs gas	50% excess air		.18
MN	.3	gr/scf	12% CO_2	<200 lbs/hr	.3
	.2	gr/scf	12% CO_2	200-2000 lbs/hr	.2
	.1	gr/scf	12% CO_2	>2000 lbs/hr	.1
MS	.2	gr/scf	12% CO_2	Design capacity	.2
	.1	gr/scf	12% CO_2	New sources near resid. areas	.1
MO	.2	gr/scf	12% CO_2	≥200 lbs/hr (new)	.2
	.3	gr/scf	12% CO_2	All others	.3
MT	.3	gr/scf	12% CO_2	≤200 lbs/hr	.3
	.2	gr/scf	12% CO_2	>200 lbs/hr	.2
	.1	gr/scf	12% CO_2	New sources	.1
NE	.2	gr/scf	12% CO_2	<2000 lbs/hr	.2
	.1	gr/scf	12% CO_2	≥2000 lbs/hr	.1

TABLE 2-4 (CONTD.)

EMISSION LIMITATIONS FOR EXISTING MUNICIPAL INCINERATORS

State	Regulation				Equivalent Common Regulation gr/scf@12%CO_2
	Value	Units	Corrected To	Process Conditions	
NV	Calculate	$E = 40 - 7 \times 10^{-5}R$	R, E = lb/hr	>2000 lbs/hr	.04
NH	.3	gr/scf	12% CO_2	≤200 lbs/hr	.3
	.2	gr/scf	12% CO_2	>200 lbs/hr (new)	.2
	.08	gr/scf	12% CO_2	>50 TPD	.08
NJ	.1	gr/scf	12% CO_2		.1
NM		Prohibition			0
NY State	.3	lb/hr		<100 lb/hr	.32
	3.0	lb/hr		@ 1000 lb/hr	.32
	21	lb/hr		@ 10,000 lb/hr	.22
	130	lb/hr		@ 100,000 lb/hr	.14
City	2.0	lb/hr		@ 1,000 lb/hr	.21
	15	lb/hr		@ 10,000 lb/hr	.16
	80	lb/hr		@ 100,000 lb/hr	.085
NC	.4	lbs/hr		≥22,000 lbs/hr	.017
ND	Calculate	lbs/hr $E = .0252R^{.67}$ (R = lbs/hr)		>1,000 lbs/hr	.09
OH	.1	lbs/100 lbs charged		≥100 lbs/hr	.11
	.2			<100 lbs/hr	.21
OK	Calculate	lbs/hr $E = .01221R^{.7577}$ (R = lbs/hr)		>100 lbs/hr	.11
OR	.3	gr/scf		≤200 lbs/hr	.3
	.2	gr/scf		>200 lbs/hr (existing)	.2
	.1	gr/scf		>200 lbs/hr (new)	.1
PA	.1	gr/scf	12% CO_2		.1
RI	.16	gr/scf	12% CO_2	<2000 lbs/hr	.16
	.08	gr/scf	12% CO_2	≥2000 lbs/hr	.08

TABLE 2-4 (CONTD.)

EMISSION LIMITATIONS FOR EXISTING MUNICIPAL INCINERATORS

State	Regulation				Equivalent Common Regulation gr/scf@12%CO_2
	Value	Units	Corrected To	Process Conditions	
SC	.6	lbs/10^6BTU			.28
SD	.2	lbs/100 lbs charged			.21
TN	.2 .2 .1	% of charging rate % of charging rate % of charging rate		<200 lbs/hr 200-2000 lbs/hr >2000 lbs/hr	.21 .21 .11
TX	Calculate	$E = .048Q^{.62}$	E = lbs/hr Q = ACFM	>1000 ACFM	.30
UT	.08	gr/scf	12% CO_2	>50 TPD	.08
VT	.1	lbs/100 lbs charged			.11
VA	.14	gr/scf	12% CO_2		.14
WA	.1	gr/scf	7% O_2		.3
WV	8.25 5.43 2.72	lbs/hr lbs/hr lbs/hr		≤200 lbs/hr 200-15000 lbs/hr >15000 lbs/hr	4.4 .04 .01
WI	.15 .2 .3 .5 .6	lbs/1000 lbs gas lbs/1000 lbs gas lbs/1000 lbs gas lbs/1000 lbs gas lbs/1000 lbs gas	12% CO_2 12% CO_2 12% CO_2 12% CO_2 12% CO_2	≥ 4000 lbs/hr } built 500-4000 lbs/hr } after ≤ 500 lbs/hr } 4/1/72 > 500 lbs/hr } built ≤ 500 lbs/hr } before 4/1/72	.08 .11 .16 .26 .32
WY	.2	lbs/100 lbs charged			.21
Wash D.C.	.08	gr/scf	12% CO_2		.08

Note:

A 300 TPD facility, operating 3 shifts/day was assumed where appropriate

= 0.94 lbs/100 lbs refuse

= 0.89 gr/scf @ 50% excess air

= 1.26 grams/Nm^3 at 7% CO_2

On December 23, 1971, standards of performance for municipal incinerators of greater than 50 tons per day charging rate were promulgated pursuant to Section 111 of the Clean Air Act. These regulations applied to all incinerators for which construction or modification had begun after August 17, 1971, limiting particulate emissions from such facilities to 0.08 grains/standard cubic foot corrected to 12% CO_2, maximum two hour average. The enforcement of this regulation is the responsibility of the Federal EPA; however, in many cases, they have delegated the authority to individual states.

3.0 MUNICIPAL INCINERATION AND AIR POLLUTION

3.1 Process Description

3.1.1 Combustion

Solid waste incineration, when carried out under the proper combination of turbulence, time and temperature, is capable of reducing the charge to a non-combustible residue consisting only of the glass, metal and masonry materials present in the original charge.

Drying & Ignition

Since most municipal solid waste contains substantial quantities of both surface and internal moisture, a drying process is necessary before ignition can occur and the combustion process can proceed. This drying process continues throughout the entire length of the furnace, but proceeds at the greatest rate immediately following charging of the solid waste. Once moisture is removed, the temperature of the substance can be raised to the ignition point, although the outer surface of a solid may be dried and ignited before the inner material is dried.

To facilitate drying, some furnace designs use preheated air or incorporate reflecting arches to radiate heat stored from the burning of previously charged material. The first part of the grate system is also frequently referred to as the drying grate. Ignition takes place as the solid waste is dried and continues through the furnace. The portion of the grates where ignition first occurs is often called the ignition grate.

Primary & Secondary Combustion

The incineration combustion process is thought of as occurring in two overlapping stages - primary combustion and secondary combustion.

Primary combustion generally refers to the physical-chemical changes occurring in proximity to the fuel bed and consists of drying, volatilization, and ignition of the solid waste. Secondary combustion refers to the oxidation of gases and particulate matter released by primary combustion. To promote secondary combustion, a sufficiently high temperature must be maintained, sufficient air must be supplied, and turbulence or mixing should be imparted to the gas stream. This turbulence must be intense and must persist long enough to ensure thorough mixing at the temperatures required for complete combustion.

Combustion Air

In the combustion process, oxygen is needed to complete the chemical reaction involved in burning. The air necessary to supply the exact quantity of oxygen required for the chemical reactions is termed stoichiometric or theoretical air. Any additional air supplied to the furnace is termed excess air and is expressed as a percentage of the theoretical air.

Air that is purposely supplied to the furnace from beneath the grates is termed underfire air. Overfire air is that air introduced above the fuel bed; its primary purpose, in addition to supplying oxygen, is to provide turbulence. Infiltration air is the air that enters the gas passages through cracks and openings and is frequently included in the figure for overfire air.

The proportioning of underfire air and overfire air depends on incinerator design; very often, however, the best proportions are determined by trial and error. For most municipal incinerator designs, underfire air ranges from 40 to 60 percent of the total air. This amount of underfire air should provide acceptable combustion in the fuel bed and adequate grate cooling. In general, as the underfire air is decreased, the burning rate is inhibited; but with increasing underfire air, particulate emissions are likely to increase.

To supply adequate air for complete combustion and to promote turbulence, a minimum of 50 percent excess air should be provided. Too much excess air, however, can be detrimental because it lowers furnace temperatures. In general, refractory furnaces require 150 to 200 percent excess air, whereas water wall furnaces require only 50 to 100 percent excess air.

Furnace Temperatures

At the air intake, combustion air may be either at ambient temperature or preheated, depending on furnace design. Immediately above the burning waste, the temperature of the gases generally ranges from 2100° to 2500° F, and for short periods of time, it may reach 2800° F in localized areas. When the gases leave the combustion chamber, the temperature should be between 1400° to 1800° F and the gas temperature entering the stack should be less than 1000°F. Where induced draft fans, electrostatic precipitators, and other devices requiring lower gas temperatures are used, the gases will have to be cooled even further to about 500° to 700° F.

Furnace temperature varies considerably, depending on where it is measured. The most widely accepted location for measuring and reporting furnace temperature is near the roof at the exit of the combustion chamber. At this location, the temperature should be maintained between 1,400 and 1,800° F to ensure that proper combustion has occurred. Most incinerator designs are based on temperatures within this range, however, in practice, operating temperatures frequently fluctuate by 200° F or more, sometimes in a matter of minutes. The furnace temperature should be maintained at fairly constant levels, preferably in midrange since such operation will accommodate sudden temperature changes.

Regulation of the combustion process through control of furnace and flue gas temperatures is achieved principally through the use of excess air, water evaporation, and heat exchange. Of these, the use of excess air is the most common and, in refractory furnaces, is often the only method of control. Even when another cooling method is available, some excess air is still used but primarily for ensuring turbulence and complete combustion.

3.1.2 Furnaces

The combustion process takes place in the furnace of the incinerator, which includes the grates and combustion chambers. There are numerous designs or configurations of furnaces to accomplish combustion, and, to date, no one design can be considered the best.

Furnaces commonly used for the incineration of municipal solid waste are the vertical circular furnace, the multicell rectangular furnace, the rectangular furnace, and the rotary kiln furnace. Although these furnaces vary in configuration, total space required for each is based on a heat release rate of about 18,000 Btu per cubic foot of furnace volume per hour, however, heat release rates can vary from 12,500 to 25,000 Btu per cubic foot.

The vertical circular furnace is usually refractory lined. Solid waste is charged through a door or lid in the upper part (usually the ceiling) and drops onto a central cone grate and the surrounding circular grate (Figure 3-1). Underfire forced air is the primary combustion air and also serves to cool the grates. As the cone and arms rotate slowly, the fuel bed is agitated and the residue works to the sides where it is discharged, manually or mechanically, through a dumping grate on the periphery of the stationary circular grate. Stoking doors are provided for manual agitation and assistance in residue dumping if necessary. Overfire air is usually introduced to the upper portion of the circular chamber. A secondary combustion chamber is adjacent to the circular chamber. Many furnaces of this design are in operation today.

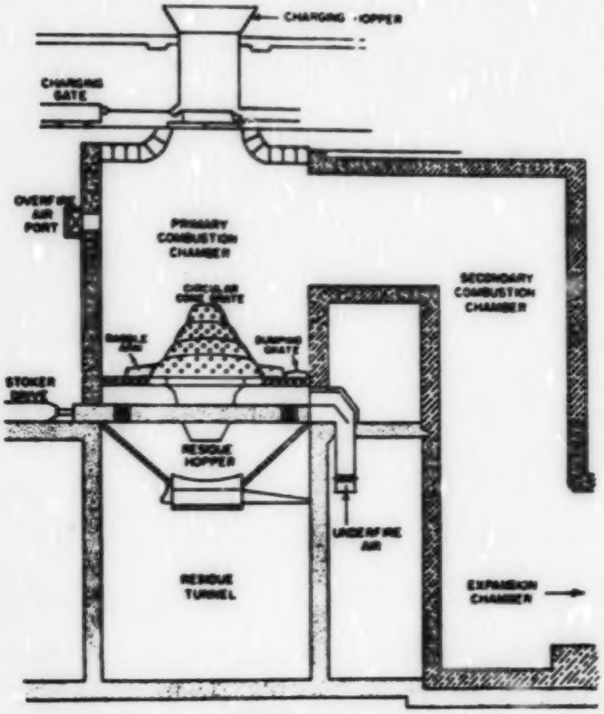
CHARGING HOPPER
CHARGING GATE
OVERFIRE AIR PORT
PRIMARY COMBUSTION CHAMBER
CIRCULAR CONE GRATE
RABBLE ARM
DUMPING GRATE
STOKER DRIVE
RESIDUE HOPPER
SECONDARY COMBUSTION CHAMBER
UNDERFIRE AIR
RESIDUE TUNNEL
EXPANSION CHAMBER

Figure 3-1

Vertical Circular Furnace

The multicell rectangular furnace, also called the mutual assistance furnace, may be refractory lined or water cooled; it contains two or more cells set side-by-side, and each cell normally has rectangular grates (Figure 3-2). Solid waste is usually charged through a door in the top of each cell. Generally, the cells of the furnace have a common secondary combustion chamber and share a residue disposal hopper.

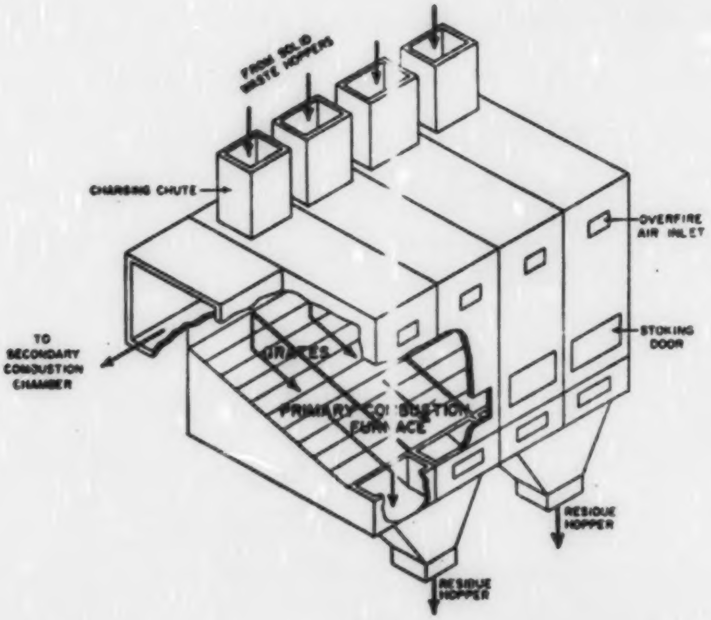
FROM SOLID WASTE HOPPERS
CHARGING CHUTE
OVERFIRE AIR INLET
TO SECONDARY COMBUSTION CHAMBER
GRATES
STOKING DOOR
PRIMARY COMBUSTION FURNACE
RESIDUE HOPPER
RESIDUE HOPPER

Figure 3-2
Multicell Rectangular Furnace

The rectangular furnace is the most common type of recently constructed municipal incinerator (Figure 3-3). Several grate systems are adaptable to this form. Commonly, two or more grates are arranged in tiers so that the moving solid waste is agitated as it drops from one level to the next level. Each furnace has only one charging chute. Secondary combustion is frequently accomplished in the aft end of the furnace which is separated from the front half by a curtain wall. This wall serves to radiate heat energy back towards the charging grate to promote drying and ignition as well as to increase combustion gas velocity and the level of turbulence.

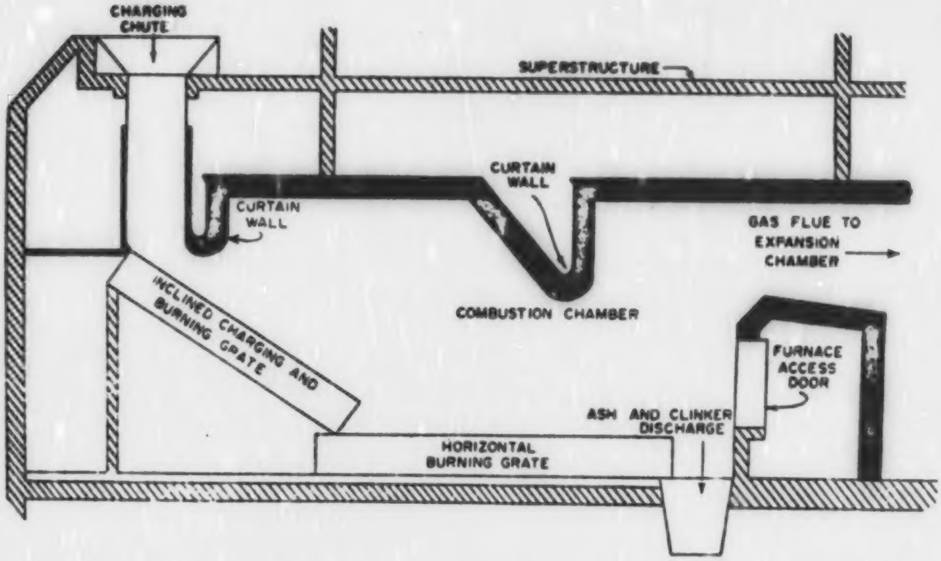
CHARGING CHUTE
SUPERSTRUCTURE
CURTAIN WALL
CURTAIN WALL
GAS FLUE TO EXPANSION CHAMBER
COMBUSTION CHAMBER
INCLINED CHARGING AND BURNING GRATE
FURNACE ACCESS DOOR
ASH AND CLINKER DISCHARGE
HORIZONTAL BURNING GRATE

Figure 3-3
Rectangular Furnace

A rotary kiln furnace consists of a slowly revolving inclined kiln that follows a rectangular furnace where drying and partial burning occurs (Figure 3-4). The partially burned waste is fed by the grates into the kiln where cascading action exposes unburned material for combustion. Final combustion of the combustible gases and suspended combustible particulate occurs in the mixing chamber beyond the kiln discharge. The residue falls from the end of the kiln into a quenching trough.

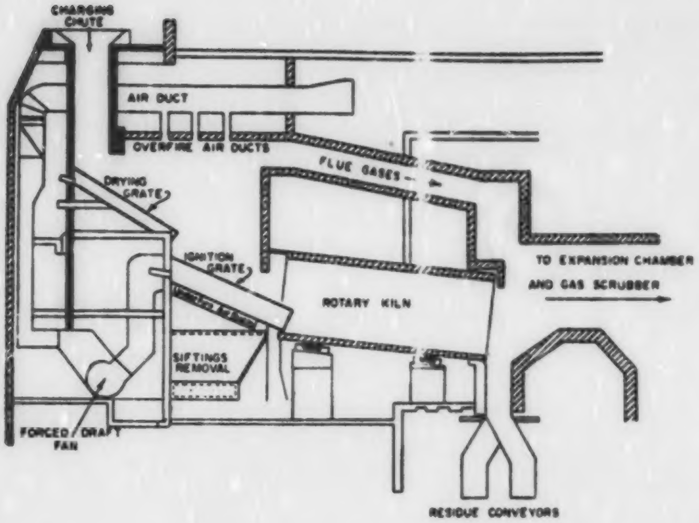
CHARGING CHUTE
AIR DUCT
OVERFIRE AIR DUCTS
FLUE GASES
DRYING GRATE
IGNITION GRATE
ROTARY KILN
TO EXPANSION CHAMBER AND GAS SCRUBBER
SIFTINGS REMOVAL
FORCED DRAFT FAN
RESIDUE CONVEYORS

Figure 3-4
Rotary Kiln Furnace

3.1.3 Grate Systems

A grate system must transport the solid waste and residue through the furnace and, at the same time, promote combustion by adequate agitation and passage of underfire air. The degree and methods of agitation on the grates are important. The abrupt tumbling encountered when burning solid waste drops from one tier to another will promote combustion. Abrupt tumbling, however, may contribute to entrainment of excessive amounts of particulate matter in the gas stream. Continuous gentle agitation promotes combustion and limits particulate entrainment. Combustion is largely achieved by air passing through the waste bed from under the grate, but excessive amounts of underfire air contribute to particulate entrainment. Some inert materials, such as glass bottles and metal cans, aid combustion by increasing the porosity of the fuel bed. Conversely, inert materials inhibit combustion if the materials clog the grate opening.

Mechanical grate systems must withstand high temperatures, thermal shock, abrasion, wedging, clogging, and heavy loads. Such severe operating conditions can result in misalignment of moving parts, bearing wear, and warping or cracking of castings.

Ordinarily, the design value for grate loading will be between 50 and 70 pounds per square foot per hour. This design value depends mostly on the type of solid waste and grate design, but also depends on the other elements of the furnace. The grate loading is often expressed in Btu's per square foot per hour. An average rating of 300,000 Btu per square foot of grate per hour is often used as a design parameter.

Grate systems may be classified by function, such as drying grate, ignition grate, and combustion grate. Grates for solid waste incineration may also be classified by mechanical type. They include traveling, reciprocating, oscillating, and reverse reciprocating grates; multiple rotating drums; rotating cones with arms; and variations or combinations of these types. In the United States, traveling, reciprocating, rocking, rotary kiln, and circular grates are most widely used.

Traveling grates are continuous, belt-like conveyors (Figure 3-5). A single traveling grate does not promote agitation but two or more grates at different elevations do provide some agitation as the material drops from one level to the next.

In reciprocating grate systems, the grate sections are stacked like overlapping roof shingles (Figure 3-6). Alternate grate sections slide back and forth while adjacent grate sections remain fixed. Like traveling grates, reciprocating grates may be arranged in multiple-level series providing additional agitation as the material drops from one grate to the next.

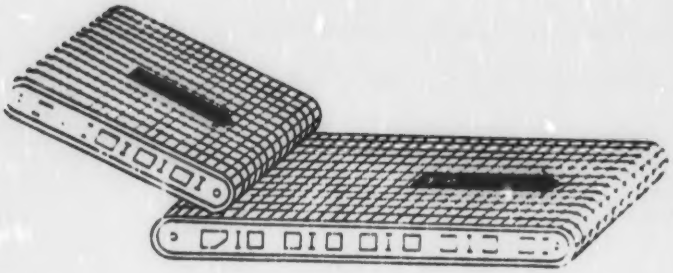

Figure 3-5

Traveling Grates

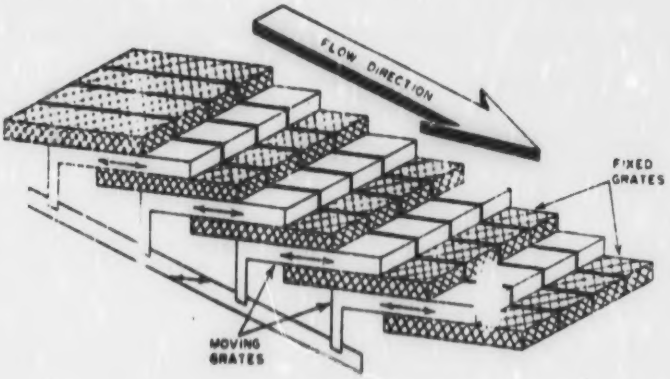
FLOW DIRECTION
FIXED GRATES
MOVING GRATES

Figure 3-6

Reciprocating Grates

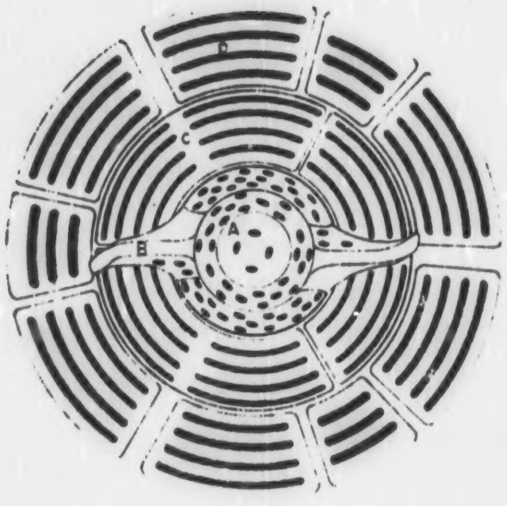

Figure 3-8

Circular Grates

A - Rotating Cone
B - Extended Stoking Arm
(Rabble Arm)
C - Stationary Circular Grate
D - Peripheral Dumping Grate

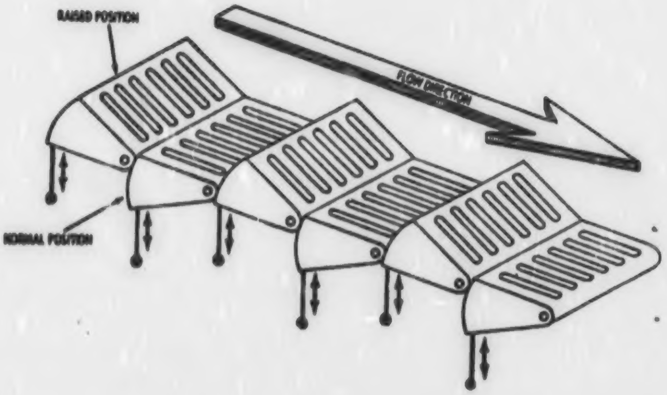
RAISED POSITION
FLOW DIRECTION
NORMAL POSITION

Figure 3-7

Rocking Grates

Rocking grates are arranged in rows across the width of the furnace, at right angles to solid waste flow. Alternate rows are mechanically pivoted or rocked to produce an upward and forward motion, thus advancing and agitating the solid waste (Figure 3-7). Rocking grates can also be arranged in series.

The rotary kiln has a solid refractory surface and is commonly preceded by a reciprocating grate. The slow rotation of the kiln, which is inclined, causes the solid waste to move forward in a slowly cascading motion.

The circular grate, in the vertical circular furnace, is commonly used in combination with a central rotating cone grate with extended rabble arms that agitate the fuel bed (Figure 3-8).

3.1.4 Charging of Solid Waste

Solid waste is charged either continuously or in batches. In the continuous process, solid waste is fed to the furnace directly through a rectangular chute that is kept filled at all times to maintain an air seal. In the batch process, solid waste is fed to the furnace intermittently through a chute, or the furnace may be fed directly by opening the charging gate and dropping the waste directly from a crane bucket, front end loader, or bulldozer. A ram can also be used to feed a batch of material directly on to the grate through an opening in the furnace wall. Continuous feed minimizes irregularities in the combustion system. Batch feeding causes fluctuations in the thermal process because of the non-uniform rate of feeding and intermittent introduction of large quantities of cool air.

3.1.5 Residue Removal

Residue, or all of the solid material remaining after burning, includes ash, clinkers, tin cans, glass rock, and unburned organic substances. Residue removal can be either a continuous operation or an intermittent batch process. In a continuous feed furnace, the greatest volume of residue comes off the end of the burning grate; the remainder comes from siftings and from fly ash. The residue from the grate must be quenched and removed from the plant.

Batch operated furnaces usually have ash collection and storage hoppers beneath the grates. Periodically, residue is removed, quenched, accumulated in a residue hopper, and discharged from the bottom by opening a watertight gate. The discharge may be placed into trucks or other containers for transport to a disposal area. Access to the residue hoppers is usually by a tunnel beneath the furnace floor. Provisions are generally made for adequate ventilation and dust removal in this area. Excess quench water is drained before trucks are loaded, and the residue trucks or containers are generally watertight. Residue trucks dripping quench water to the disposal site are unsightly, unsanitary, and they invite complaints from the community.

In many continuous feed operations, residue is discharged continuously into a trough or troughs connected to all furnaces. A slow-moving drag conveyor, submerged in the water-filled trough, continuously removes the residue. Usually the discharge end of the conveyor is inclined to allow drainage of excess quench water from the residue before loading into a holding hopper or directly into trucks. The residue conveyor system must be ruggedly constructed to withstand heavy loads and continuous use. The residue is highly abrasive, and the quench water is highly corrosive. Since the residue is discharged to the conveyor below water, this system has the advantage of maintaining an air seal to the furnace.

Siftings are the fine materials that fall from the fuel bed through the grate openings during the drying, ignition, and burning processes. They consist of ash, small fragments of metal, glass and ceramics, and unburned or partially burned organic substances. In some designs, siftings are collected in troughs and conveyed continuously by sluicing or mechanical means to a residue collection area. In other designs, siftings are collected and returned continuously by a conveyor to the furnace. They may also be removed by the batch method. If siftings containing highly combustible materials such as oil, plastics, and grease, accumulate unquenched beneath the grate, they can burn and cause heat damage to the grates above.

3.1.6 Exhaust Gas Treatment

The burning of solid waste generates heat that expands the volume of gas. The gas passages, air pollution control devices, and stack must satisfactorily accommodate this gas. An estimate of the quantities of gaseous products of combustion can be calculated from the ultimate analyses of solid waste and knowledge of the amount of combustion air introduced. Gas velocities must be determined so that gas passages can be sized to prevent excessive settlement of entrained particles, while minimizing pressure losses.

To adequately control the combustion process, the draft must be regulated. Dampers are generally used in both natural draft stacks and in stacks employing induced draft fans of constant speed. Adjustable speed, induced draft fans are also used to control draft and improve combustion conditions. In addition, induced draft fans are required on incinerators incorporating high efficiency air pollution control equipment (precipitators and scrubbers) because of either the high pressure drop requirements or the need for control of the volume throughput.

Incinerator stacks provide for the atmospheric dispersion of gases and particulate matter and as the draft mechanism in the case of natural draft furnaces. The required height of the stack is a function of ambient air quality, health effects, Federal Aviation Agency Regulations, architecture and other constraints.

Water injected into the hot gas stream cools the flue gas through evaporation of the water and adsorption of heat during superheating of the water vapor. Although the water vapor adds to the total gas volume in a manner similar to the addition of excess air, the total of water vapor and cooled gases is smaller than the original volume of gases. Some economy may result from reducing this volume of gas to be treated; however, the cost of water should also be considered.

Heat exchange through the use of water tube walls and boilers, a well-established European practice, is attracting greater attention in the United States. A distinct advantage of heat exchangers in cooling gases is that additional gases or vapors are not added to the gas flow to reduce temperature and significantly smaller gas volume results. Because gas volume is greatly reduced, the size of collection devices, fans and gas passages can be reduced. Heat recovery and utilization can bring further economies through the sale of steam or the generation of electricity.

3.2 Environmental Impact

On a nationwide basis, municipal incinerators contribute a very small portion of the total air pollutants generated by stationary combustion sources and are responsible for only a fraction of the water pollution resulting from industrial-type operations. On the other hand, individual facilities can contribute significantly to environmental degradation, especially in the urban areas in the northeastern part of the United States, where the majority of incinerators are located.

Municipal incinerators should not have significant negative impact on the environment if they: (1) are designed and operated to minimize emissions of smoke, odors, and unburned organic gases and vapors; (2) are equipped with air pollution control devices that will ensure compliance with air pollution emission standards; (3) treat their wastewaters either by neutralization or sedimentation on-site or by discharge to a municipal sewage treatment plant to comply with applicable standards; (4) dispose of their residue in a sanitary landfill; (5) adhere to a litter control program.

3.2.1 Air Pollution - Particulate Matter

Entrained particulate matter is the major air pollutant from the incineration of solid waste. Although there are also some environmentally detrimental gases resulting from incineration, they are not regulated on a national basis and only nominally regulated on a statewide basis. This Manual addresses itself to the emission and control of particulate matter only since it is the only pollutant presently regulated throughout the U.S.

The quantity and size of particulate emissions leaving an incinerator varies widely, depending on such factors as the type of refuse being fired, the method of feeding, operating procedures and completeness of combustion.

The control of such emissions from incineration begins, however, in the furnace. Proper design and careful operation will insure that the pollutant discharge is minimized.

Airflow delivered to the combustion process must be carefully controlled, as this can have a major effect on the pollutants emitted, both solid and gaseous. A certain amount of excess air is always required to assure proper combustion of the refuse and to avoid excessive furnace temperature. Too much excess air results in high velocities and increased carryover of particulate as well as a reduction in the furnace temperature to below that required for complete combustion. The proper use of overfire air can greatly reduce the carryover of unburned combustibles and dust by insuring their complete burnout and when properly aimed, it can knock fly ash back onto the refuse bed. The proper delivery and quantity of underfire air can minimize particle entrainment while maximizing combustion efficiency. Fly ash carryover from the refuse on the grate will increase approximately as the square of the air velocity through the grate. This is, therefore, one factor in limiting the combustion rate on the grate, as it is easier and less costly to reduce emissions leaving the furnace than it is to remove them from the stack gas. NO_x and SO_3 emissions are also increased when too much air passes through the furnace.

Flame travel, or the height of the flame above the refuse bed, increases with the combustion rate as well as with the volatile and moisture contents of the refuse. The furnace must, therefore, be large enough to permit burnout of this flame either in the primary chamber or in the secondary chambers. When these are too small, the flame may carry over into the stack thus resulting in fire hazard and incomplete combustion with undesirable gaseous emissions. It is generally preferable to provide this flame travel in a vertical direction so that the burnout occurs in the primary chamber. This assures more complete combustion and reduced carryover.

The important properties of the entrained particulate matter, from the standpoint of its collection are the mass loading, particle size distribution, specific gravity, electrical resistivity and chemical composition. Studies[4] of incinerators ranging in size from 50 to 250 tons per day employing a variety of grate configurations have quantified such parameters. Values of particulate emissions were found to vary from 10 to over 60 pounds per ton of solid waste burned. The relationship of these emissions to underfire air is shown in Figure 3-9. Particle size distribution and specific gravity are critical to the performance of most particulate collectors and essentially determine the level of sophistication required to meet a given emission limitation. Data on typical particle size distribution, specific gravity and combustible content of entrained particulate are shown in Figure 3-10 for three continuous-feed, refractory furnace incinerators. Because the nature of the waste charged and furnace conditions have a material effect on such determinations, caution must be exercised in generalizing from this information.

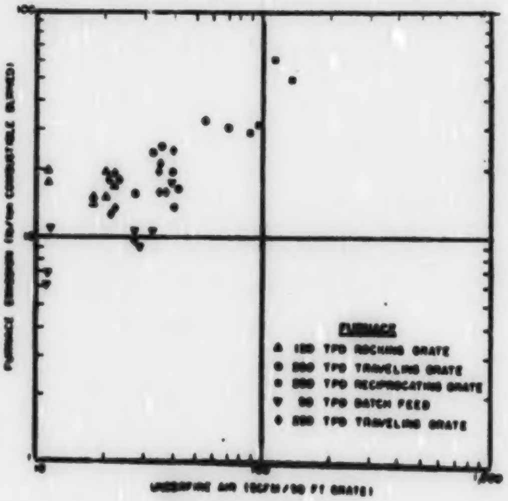

Figure 3-9

Entrained Particulate Emissions

Physical analysis	Installation 1 (250 TPD)	 2 (250 TPD)	 3 (120 TPD)
Specific gravity (gm/cc)	2.65	2.70	3.77
Bulk density (lb/cf)	-	30.87	9.4
Loss of ignition at 750 C (%)	18.5	8.15	30.4
Size distribution (% by weight)			
< 2μ	13.5	14.6	23.5
< 4μ	16.0	19.2	30.0
< 6μ	19.0	22.3	33.7
< 8μ	21.0	24.8	36.3
< 10μ	23.0	26.8	38.1
< 15μ	25.0	31.1	42.1
< 20μ	27.5	34.6	45.0
< 30μ	30.0	40.4	50.0

Figure 3-10

Properties of Particulates Leaving Furnace

Electrical resistivity of the fly ash is the property of prime interest when electrostatic precipitators are considered for particulate collection. High resistivity particulates cause disturbances in electrical operation that reduce collection rates. In general, collection of particulates with higher resistivities requires larger and more expensive precipitators. Wet scrubbers or fabric filters may be preferred if resistivity is very high. Very low resistivities are also troublesome, but can be handled in properly designed precipitators. When the resistivity is low, the dust readily loses its charge to the collecting electrode; this can cause the particle, particularly if it is large, to be reentrained in the gas stream.

The optimum resistivity range for efficient operation of an electrostatic precipitator lies between 10^4 and 10^{10} ohm-cm. Thus, to select the most suitable air pollution equipment, the resistivity of the fly ash must be known. Figure 3-11 presents typical resistivity-temperature curves

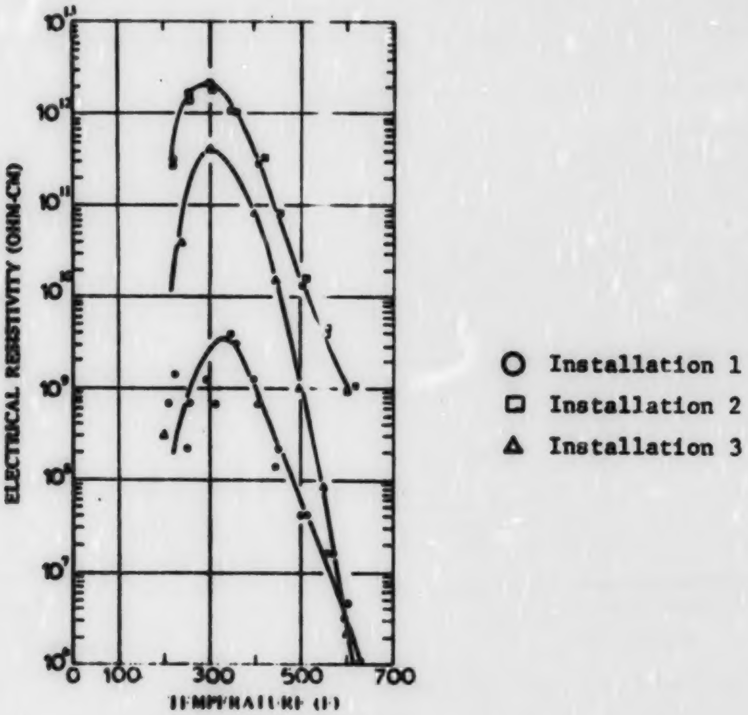

Figure 3-11

Typical Resistivity-Temperature Curves

of entrained particulates leaving large, continuous feed refractory furnace incinerators.

3.2.2 Air Pollution - Gaseous Emissions

Both nitrogen oxide and sulfur oxide emissions occur in solid waste incineration, but the amounts per ton of fuel burned are several orders of magnitude below those involved in the combustion of fossil fuel. Solid waste is inherently a "clean fuel" from the standpoint of sulfur content, with a value of about 0.2 percent by weight as compared to most coals and residual oils used today, which range from about 1 to 3 percent sulfur. Further, there is evidence to suggest that for incinerators, most of the sulfur is retained in the ash rather than as oxides in the stack. Thus, sulfur oxide emissions from solid waste incineration generally are well below even the most stringent present or anticipated restrictions. It is not likely that NO_x emissions will be regulated in the immediate future since emission levels are only one-tenth of those from fossil fuel combustion.

Some concern has been expressed about emissions of hydrogen chloride (HCL) that might occur as a result of incineration of certain plastics - namely polyvinyl chloride. Hydrogen chloride is irritating to the eyes and respiratory system, and if the amounts released during incineration were great enough, a health problem would exist. If hydrogen chloride emissions become a problem, control will be necessary, but since this gas is highly soluble in water, it can be effectively removed by water scrubbers.

3.2.3 Water Pollution

Almost without exception, all incinerator plants utilize water for residue quenching. In addition, many plants use water for wet bottom expansion chambers, for cooling charging chutes, for fly ash sluicing, for residue conveying, and for air pollution control. The quantity of water required depends on plant design, on how well the system is operated, and whether water is recirculated. Total water requirements without recirculation, for a 300 ton-per-day plant with two 150 ton continuous feed furnaces have been reported(4) to be about 2,000 gallons per ton of solid waste charged. Quenching and conveying used 1,800 gallons and the wetted baffle dust collection system used 200 gallons. The study cited indicated that the use of a recirculation, clarification, and neutralizing system reduced the total water needed from 2,020 to 575 gallons per ton of solid waste.

Because of extreme variation in incinerator design, generalizing on water requirements is of only limited value. A rule of thumb, however, is that residue quenching and ash conveying at most plants requires 1,000 to 2,000 gallons of water per ton of solid waste processed. With water treatment and recirculation, total water consumption can often be reduced 50 to 80 percent.

Incineration process water can contain suspended solids, inorganic materials in solution, and organic materials that contribute to biochemical and chemical oxygen demand. A limited study(4) of incinerator wastewaters from a 50-ton-per-day, batch feed incinerator and from a 300-ton-per-day continuous feed municipal incinerator showed the presence of bacteria in the waste water from both operations. The cited studies indicated that incinerator process waters can be contaminated and, therefore, should not be discharged indiscriminately to streams or other open bodies of water. The most straightforward control is the discharge of these waters to a sanitary sewer for subsequent handling in a central treatment plant. If the waste process waters cannot be ultimately discharged to a sanitary sewer, the incinerator plant should be equipped with suitable means for primary clarification, pH adjustment, and if necessary, biological treatment to meet local standards.

Water used for dust control and for periodic washdown to control insects and rodents is a potential pollutant. Current practice makes no attempt to integrate these waters into in-plant water treatment facilities, but allows drainage to surface waters or sanitary sewers. The pollution is considered minimal compared with that of other process waters. Even so, they should be conveyed to an onsite or offsite treatment process.

Incinerator residue is permeable and may contain water soluble inorganic compounds. If water moves through the deposit of residue, leaching can occur. Pollution can result if the leachate water moves through the underlying soil and enters the groundwater. Surface water can also become contaminated where the leachate moves laterally through the surrounding soil. In many cases, therefore, only sanitary landfill methods can be employed to dispose of incinerator residue.

Where there is no danger of water pollution, residue may be used as a fill material if the residue does not attract insects or rodents.

4.0 AIR POLLUTION CONTROL TECHNOLOGY

The emphasis on controlling air pollutants from municipal incinerators has been primarily on the reduction of particulate emissions. Over the years, improved combustion in modern municipal incinerators has reduced particulate emissions and smoke, but uncontrolled particulate emissions are still significant, and must be controlled to meet current emission and air quality standards. This section will discuss particulate emission control technology applicable to municipal incinerators. Control of gaseous pollutant emissions will not be considered specifically.

4.1 Evolution of Particulate Controls

4.1.1 Settling Chamber

The most rudimentary form of particulate collection system is the settling chamber (also called an expansion or subsidence chamber). The settling chamber is basically an enlargement in the incinerator exhaust ductwork that provides for a decrease in gas velocity and allows the larger particles to settle out. Settling chambers can be of dry or wet bottom construction. With the exception of a few units with sprays or spray-baffle systems, settling chambers represented the state-of-the-art in the early 1950's. Collection efficiencies for settling chambers are well below 50 percent.

At about this same time, some attempts were made to further reduce particulate emissions by installing checkers at the outlet of settling chambers to provide some degree of dry particulate impingement. In other cases, settling chambers were converted to water spray chambers to create a rudimentary scrubber. Such modifications provided only limited collection efficiency improvement over simple settling chambers.

In 1949, the American Society of Mechanical Engineers (ASME) issued a Model Ordinance that limited particulate emissions from combustion sources to 0.85 lb/1,000 lb of flue gas at 50% excess air. An uncontrolled incinerator emits about 30 pounds of particulate per ton[*] of refuse charged, which would be equivalent to 2.7 lb/1,000 lb flue gas at 50% excess air. Therefore, application of the ASME model ordinance required an overall particulate collection efficiency of at least $100\ (1 - \frac{.85}{2.7}) = 69\%$. For an incinerator already fitted with a settling chamber and spray system, the additional collection efficiency needed to conform to this standard would have been only about 33%.

4.1.2 Wetted Baffle

During the late 1950's, the ASME-recommended emission limitation was incorporated into many local ordinances and applied to municipal incinerators. One method used to meet this standard was the installation of flooded or spray-wetted baffles in the incinerator outlet to provide wetted impingement surfaces for collection and removal of particles. These devices offered little resistance to the flow of gases (0.3 to 0.6 in. water gauge pressure drop) and a natural draft stack could still be used. Collection efficiencies for such devices vary widely, but are generally around 50 percent at best.

4.1.3 Mechanical Collector

Another approach used to meet the ASME standards was the installation of mechanical collectors or cyclones. This method circumvented the problem of contaminated water streams, but cyclones, because of their appreciable pressure drop (2 to 4 in. water gauge), required the use of an induced draft (ID) fan. Furthermore, cooling of the exhaust gas by air dilution or evaporation was required to protect the cyclones and ID fan from excessive temperatures. Cyclone installations were of two general types: batteries of relatively large (24 to 40 inch diameter) cyclones with involute or scroll type entry connections and batteries of a large number of small (9 to 12 inch diameter) cyclones with spinners or turning vane entries. Of the two types, the large diameter units were the more successful. The small diameter units, while giving generally higher collection efficiencies, tended to plug and wear rapidly because of smaller gas passages and higher internal velocities. Collection efficiencies for cyclones are in the range of 60 to 80 percent.

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[*] This estimate is based on AP-42.(5) If the incinerator already has a settling chamber and water spray system, emissions would be about one half of this value.

4.1.4 Wet Scrubber

During the late 50's and early 60's many municipalities were requiring more stringent particulate emission control based upon experience and legislation from air pollution control agencies on the west coast. For example, the Los Angeles County Air Pollution Control District limited "Combustion Contaminants" to 0.3 gr/scf at 12% CO_2 or about 5.6 lb/ton of refuse which is about 0.6 of the ASME required value. To meet such standards, particulate emission controls for a completely uncontrolled municipal incinerator (30 lb/ton of refuse) would be of the order of $100\ (1 - \frac{5.6}{30}) = 82\%$. Incinerators with settling chambers and sprays (14 lb/ton of refuse) would require $100\ (1 - \frac{5.6}{14}) = 60\%$ additional control.

To meet these more stringent standards, scrubbers of various designs were used to further reduce particulate emissions. Four basic scrubbing concepts evolved:

1. Multiple wetted impingement baffles.
2. Submerged entry of gases.
3. Spray wetted-wall cyclones.
4. Venturi or orifice scrubber.

The first three configurations are considered moderate to low pressure drop scrubbers (generally less than 10 in. water gauge). Since pressure drop or energy input into the scrubbing mechanism determines collection efficiency, such units are capable of only moderate collection efficiency (80 to 90 percent at best). Because of the high velocities possible in venturi and orifice scrubbers, such designs can be made to operate over a wide range of pressure drops and collection efficiencies. To meet current, tight restrictions on incinerator emissions, scrubbers with pressure drops exceeding 15 in. water gauge and collection efficiencies above 95% are required. Regardless of the collection efficiency, all scrubbers have the common problem of generating wastewater that must be disposed of.

The next section covering high efficiency particulate control devices will discuss high energy scrubbers in greater detail, together with electrostatic precipitators and fabric filters.

4.2 High Efficiency Control Devices

The degree of emission control needed for municipal incinerators to meet present and proposed emission standards requires high efficiency collector systems. The New Source Performance Standard (NSPS) for municipal incinerators may be applied to existing municipal incinerators by some local agencies as a means of further upgrading incinerators. This standard would limit emissions to 0.08 gr/scf at 12% CO_2 and would be roughly equivalent to 1.5 lb/ton of refuse. Collection efficiencies for a completely uncontrolled incinerator (30 lb/ton of refuse) would need to be at least $100\left(1 - \frac{1.5}{30}\right) = 95\%$ while an incinerator with a settling chamber and sprays (14 lb/ton of refuse) would need 100 $(1 - \frac{1.5}{14})$ = 89% additional control.

Therefore, to upgrade existing incinerators to current and expected standards, control equipment that can meet at least 90% particulate control is required. Those municipalities deciding to upgrade existing incinerators would be prudent to specify control equipment of at least 95% to 99% efficiency to make certain that the control system can adequately handle changes in character of waste and can meet even tighter emission standards should they be imposed. To meet such a requirement, there are only three categories of control technology currently available that could be considered. They will be discussed in the following sections.

4.2.1 High Energy Scrubbers

Scrubbers capable of collecting 90 to 99% of the weight of particulate matter emitted from a municipal incinerator must be able to operate at pressure drops between about 10 and 25 in. water gauge. Pressure drop, or energy input is the most important scrubber operating variable in determining collection efficiency. The most successful high efficiency scrubber design is the venturi scrubber, a schematic diagram of which is presented in Figure 4-1. In this device it is possible to obtain high velocities and a wide range of water rates within the venturi contacting section. Water rates are generally in the range of 5 to 15 gal/1,000 cubic feet of flue gas.

In contrast to impingement scrubbers where the particulates in the hot gases are impinged on a wetted surface, the venturi scrubber accelerates gases and scrubbing liquid through a venturi section producing fine liquid droplets which, because of the extremely turbulent conditions, impact directly with particulates. The "enlarged" wet particulates thus formed can

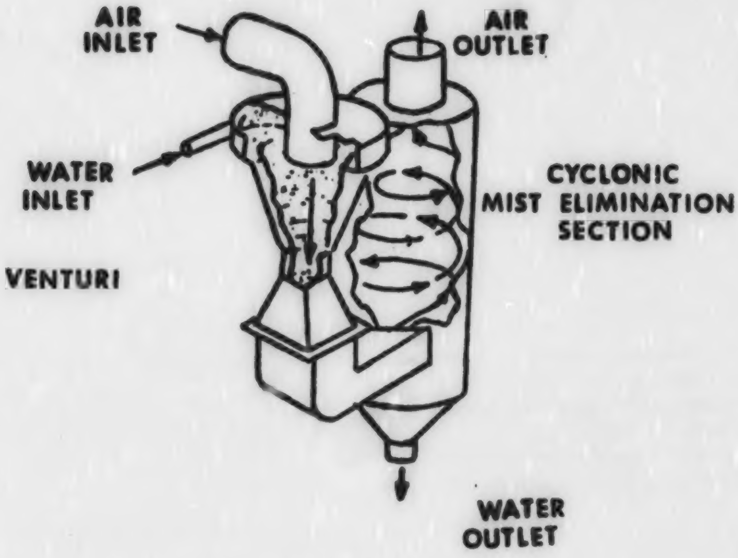


Figure 4-1
Schematic Diagram of Gas Actuated Venturi Scrubber
with Cyclonic Mist Eliminator

then be removed easily in a cyclonic separator. This cyclonic separator is often fitted with water sprays to keep the side walls clean, and to further reduce the temperature of the exhaust gases. A mist eliminator is usually required to prevent loss of liquid droplets to the atmosphere. Special high pressure fans are required for operating high efficiency venturi scrubbers.

Figure 4-2 shows a general relationship between efficiency and pressure drop used for the analysis of venturi scrubbers presented in this Manual. It is not specific to any particular installation or mechanical configuration and as such should not be used to determine compliance or erroneous conclusions could be reached. The information presented evolves from data$^{(6)}$ on fine particles and actual measured collection efficiencies on municipal incinerators.

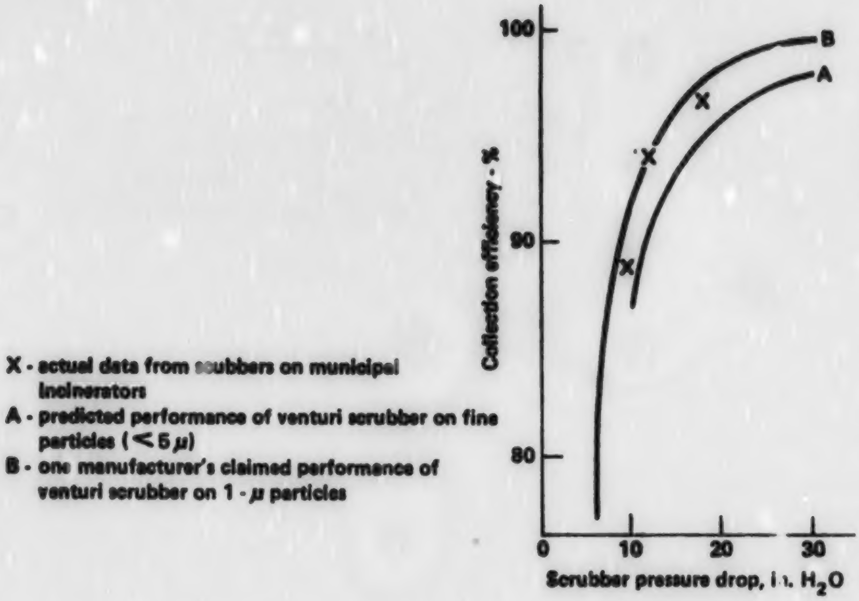


Figure 4-2

Relationship between efficiency and pressure drop in Venturi Scrubbers

The simplicity in the design of a venturi scrubber permits the use of a water-flooded wet-dry junction (the point where hot gases first meet water) which prevents many of the plugging problems inherent in other scrubber designs (e.g., wetted perforated plates, cyclones, impingement plates, plus packed towers and spray systems).

Because of the high velocities in the venturi throat and the corrosive and erosive environment, this part of the system is often lined with a refractory material such as silicon carbide. In addition, venturi scrubbers can be built with variable-area throats to permit operation at constant pressure drop over a range of flow rates.

The flooded disc scrubber can be used in many of the same applications as a venturi scrubber. This is basically a variable orifice scrubber which is simple in construction, provides a flushed wet-dry junction, can operate at constant pressure drop over a wide range of flows, and can provide the same high collection efficiencies of which the venturi scrubber is capable.

Such devices may be considered in various municipal incinerator upgrading programs.

Aside from the high energy requirements, the principal disadvantages of high efficiency scrubbers are serious corrosion problems, and the need for a liquid waste treatment system. Corrosion problems are solved by use of special construction materials, and pH control. At a water rate of 10 gal/1,000 cfm, a venturi scrubber on a 300 T/day incinerator would require about 1,000 gpm of water. Water recirculation will of course be required. In the scrubbing process the water becomes highly acidic and an alkaline material (NaOH, CaO, etc.) must be added to the recirculated water to minimize corrosion. Slag dump water is often used for at least a part of this pH control since well burned out incinerator ash produces an alkaline reaction in water.

4.2.2 Electrostatic Precipitators

The operation of an electrostatic precipitator depends upon three sequential events:

1. Charging of the particles in a corona discharge.
2. Migration of the charged particles in an electric field to and retention by a grounded collection electrode in the form of flat plates or a metal shell.
3. Removal of collected particles from the collector plates by rapping to dislodge the particles allowing them to fall into a hopper, or by flushing the collection electrode with water.

The large scale precipitators used for cleaning process or combustion emissions are single stage, i.e., the discharge and collection process take place in the same part of the precipitator. Figure 4-3 is a schematic of a typical wire and plate type precipitator. Figure 4-4 is a cut-away diagram of a typical precipitator.

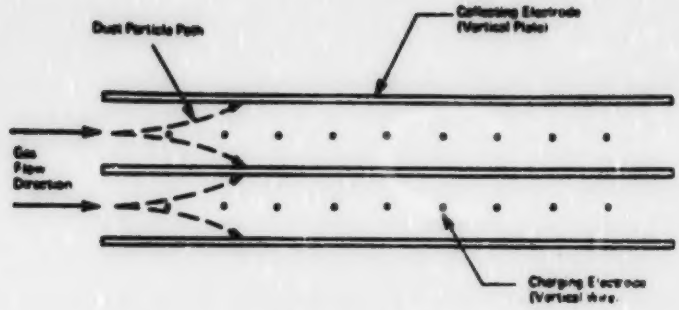

Dust Particle Path
Collecting Electrode (Vertical Plate)
Gas Flow Direction
Charging Electrode (Vertical Wire)

Figure 4-3

Schematic Drawing of Electrode Arrangement
in a Single-Stage Electrostatic Precipitator

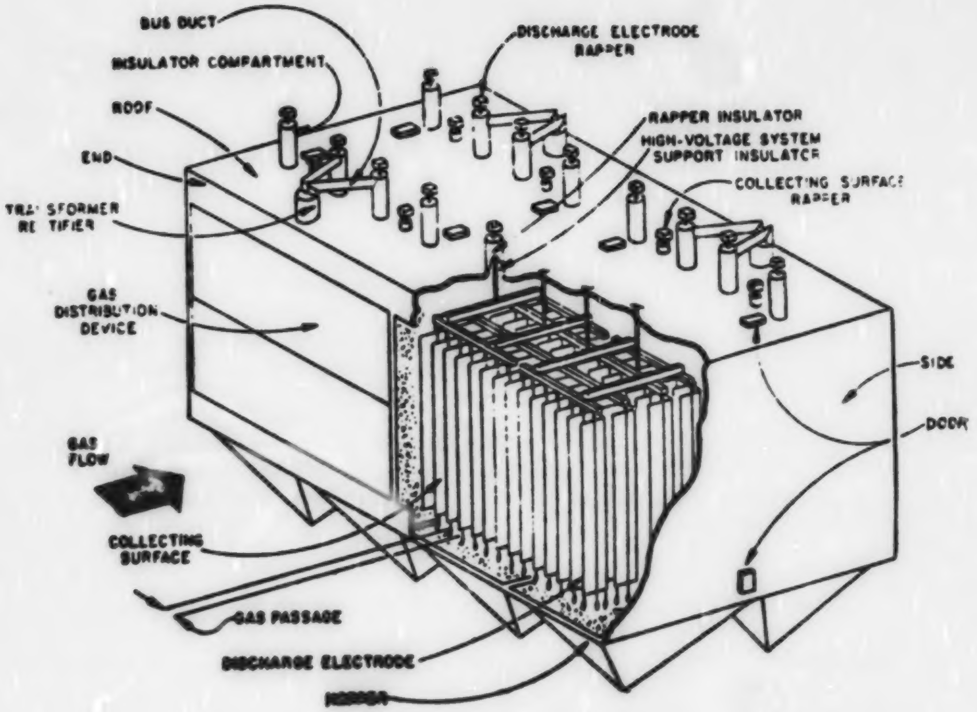

BUS DUCT
DISCHARGE ELECTRODE RAPPER
INSULATOR COMPARTMENT
ROOF
RAPPER INSULATOR
HIGH-VOLTAGE SYSTEM SUPPORT INSULATOR
END
COLLECTING SURFACE RAPPER
TRANSFORMER RECTIFIER
GAS DISTRIBUTION DEVICE
SIDE
DOOR
GAS FLOW
COLLECTING SURFACE
GAS PASSAGE
DISCHARGE ELECTRODE
HOPPER

Figure 4-4

Cut-Away View of an Electrostatic Precipitator$^{(7)}$

The charging electrodes, or discharge wires are usually energized with negative polarity by means of a rectified high voltage. The voltage gradient in the vicinity of the discharge wire exceeds the breakdown potential for the gases being treated, and an ionized region or corona discharge is formed around the wire. The negatively charged ions thus formed effectively fill the space between the plates and dust particles entering the channel formed by the collection plates receive a negative charge. The particles then migrate towards the collector plates under the influence of the electric field. Particles coming in contact with the collector plates give up their charge and are held on the plates until removed by periodic rapping.

The electrical properties of the particles and the moisture content and temperature of the gas stream affect precipitator operation. Particles of high resistivity lose their charge very slowly. This can cause accumulations of charge on the collected material and a considerable voltage difference between the surface of collected materials and the collector plates. Under these conditions, arcing may occur within the collected particle layer causing reentrainment of particles and poor precipitator performance. The resistivity of particles is temperature dependent and moisture in the gas stream tends to lower resistivity (make the surface of the particles more conductive). When evaporative cooling is used to cool incinerator gases to the optimum temperature range for a precipitator (400-600°F), the moisture added lowers particle resistivity and tends to produce stable precipitator operation. When exhaust gas cooling is achieved by air dilution or a waste heat boiler, and the incinerator emits well burned out particles, the particles may have high resistivity. Under these conditions, it may be necessary to add some moisture to the exhaust gases to achieve stable precipitator performance.

When poor combustion conditions prevail in a municipal incinerator, the particulate matter will have a large carbonaceous component that is highly conductive. In this situation the charge on the particle leaks off too rapidly upon reaching the collecting plate, and the particles do not adhere to the plate and are free to be reentrained as neutral particles.

Precipitator collection efficiency is related to collection plate area, volume flow rate and particle migration velocity in accordance with the following relationship known as the Deutsch equation:

$$\eta = 1 - e^{-W(A/V)}$$

where

A = collecting plate area
V = volume rate
W = particle migration velocity.

The migration velocity term is related to the strengths of the charging and collecting fields, particle diameter and gas viscosity. Assuming all variables except plate area are constant, a precipitator capable of collecting 95 percent of all particulate matter would have to be increased in plate area by about 50 percent to meet a 99 percent collection efficiency. Relative plate area is a rough indication of relative capital cost for precipitators.

Precipitators are classed as high efficiency devices, usually operating in the range from 95 percent to greater than 99 percent. Operating costs tend to be relatively low because of the low power requirements. Pressure drops across precipitators are usually less than 1 in. water gauge. Since particulate matter is collected dry, the problems of a wet scrubber water recirculation and cleanup system are not present.

The design of an electrostatic precipitator is based on many factors dealing not only with the gas stream and particulate matter characteristics but also on the operation and requirements of the particular installation. Table 4-1 lists the typical ranges of the major design parameters for incinerator applications.

Table 4-2 gives a partial listing of electrostatic precipitator installations on municipal incinerators in the U.S. and Canada. The major design parameters are included for comparison purposes.

Plate Spacing	20-30 cm (8-12 in.)
Velocity through Precipitator	0.9-1.8 m/sec (3-6 ft/sec)
Vertical Height of Plates	3.6-10 m (12-48 ft)
Horizontal Length of Plates[a]	0.5-1.5 x height
Applied Voltage	30,000-80,000 volts
Gas Temperature	177-343°C (350-650°F)
Gas Residence Time in Precipitator	3-6 sec
Draft Loss	3-20 mm water (0.1-0.8 in.)
Fields (electrical stages) in Direction of Gas Flow	1-4
Total Power for Precipitator	7-35 KW per m^3/min (0.2-1 KW/1000 ACFM)
Collection Area	400-1000 m^2 per 1000 m^3/min (122-305 ft^2/1000 ACFM)
Efficiency	93-99%
Gas Flow per Precipitator	850-8500 m^3/min (30,000-300,000 ACFM)
Migration Velocity[b]	6-12 cm/sec (0.2-0.4 ft/sec)

[a] Aspect ratio = [total horizontal length (depth) of collection plates] ÷ (height of collection plates) = 0.5-1.5

[b] Mean average effective migration velocity of a particle toward the collection electrode. Sometimes called precipitation rate or drift velocity.

Table 4-1

Typical Electrostatic Precipitator Design Parameters for Incinerator Applications(6)

Plant	Capacity TPD	Furnace Type[a]	Gas Flow ACFM	Gas Flow °F	Gas Velocity FPS	Residence Time Sec	Plate Area SCFM/ft^2	Input KVA	Pressure Drop in H_2O gage	Efficiency wt %
Montreal	4 × 300	WW	112,000	536	5.5	3.3	6.2	35	0.5	95.0
Stamford	1 × 220	Special R	160,000	600	6.0	3.3	6.6	57	0.5	95.0
Stamford	1 × 360	R	225,000	600	3.6	5.0	4.5	225	0.5	95.0
Stamford	1 × 150	R	75,000	600	3.7	4.9	4.6	75	0.5	95.0
NW Brooklyn	1 × 250	R	131,000	550	4.4	3.2	6.7	67	2.5	94.3
So. Shore, N.Y.	1 × 250	R	136,000	600	5.5	3.3	6.8	33	0.5	95.0
Dade City, Fla.	1 × 300	R	286,000	570	3.9	4.0	5.7	48	0.4	95.6
Chicago, NW	4 × 400	WW	110,000	450	2.9	4.6	5.5	40	0.2	96.9
Braintree, Mass.	2 × 120	WW	32,000	600	3.1	4.5	5.5	19	0.4	93.0
Hamilton, Ont.	2 × 300	WW	81,000	585	3.5	5.4	3.9	70	0.5	98.5
Washington, D.C.	6 × 250	R	130,800	550	4.1	3.9	4.9	77	0.4	95.0
Eastman Kodak	1 × 300	WW	101,500	625	3.4	5.5	3.8	106	-	97.5
Harrisburg, Pa.	2 × 360	WW	100,000	410	3.5	5.1	5.0	40	0.2	96.8

[a] R = refractory-lined; WW = waterwall

NOTE: Except for capacity, data refer to design parameters for one precipitator; several may exist

Table 4-2

Partial Listing of Electrostatic Precipitator Installations

4.2.3 Fabric Filters

The fabric filter or baghouse, when properly designed and applied to the control of particulate matter is considered to be the most efficient of all particulate control systems. While the basic removal of particulates by filtration seems simple, since it is analogous to a household vacuum cleaner, the mechanism of removal is quite complex and inadequately understood. The removal mechanism consists of elements of direct sieving, impingement, diffusion and electrostatic attraction.

While baghouses can take many forms, a typical design that might be considered for application to a municipal incinerator, would consist of a multiplicity of fabric bags closed at the top end with the bottom end connected to sleeves on a tube sheet.

Figure 4-5 is a diagram of a typical baghouse. Particulate-laden gases enter through the bottom propelled by a forced draft or induced draft fan. The baghouse is sectionalized such that one section can be isolated and the collected particles removed from the inside of the bags by shaking, collapsing, sonic blast or other methods. Dislodged particles are collected in a hopper.

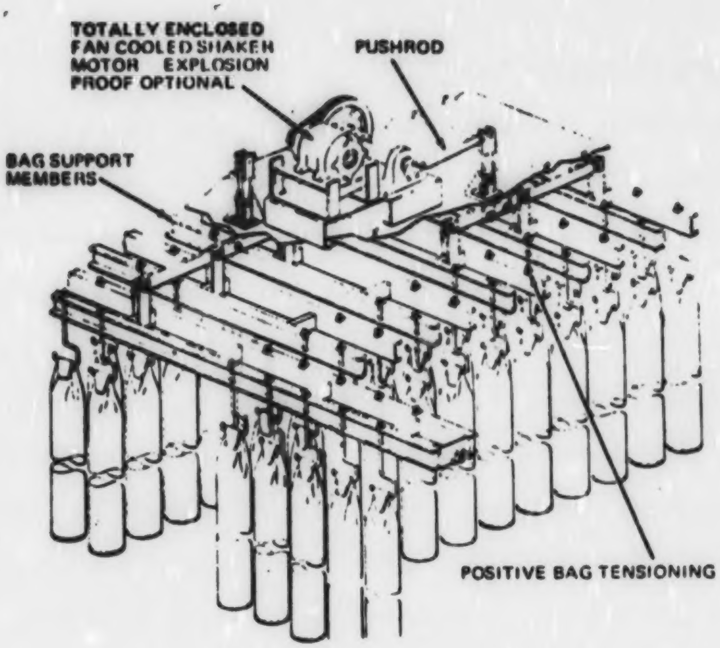

TOTALLY ENCLOSED FAN COOLED SHAKER MOTOR EXPLOSION PROOF OPTIONAL
PUSHROD
BAG SUPPORT MEMBERS
POSITIVE BAG TENSIONING

Figure 4-5
Filter Baghouse with Mechanical Shaking(6)

In order to use a baghouse installation to control municipal incinerator particulate emissions, exhaust gas temperatures must be maintained at less than 550°F - the upper limit of glass fiber bags. Other than one experimental unit, there have been no successful applications of baghouses to municipal incinerators. The principal reason is the difficulty of controlling the temperature and humidity in the gas to be treated. High temperature excursions will set a baghouse on fire, and low temperatures coupled with high moisture content will "blind" the bags, i.e., encrust them with a hard, hygroscopic deposit that cannot be dislodged short of removing the bags for washing or replacement. It is highly unlikely that a baghouse would be used to upgrade particulate control efficiency for an existing incinerator.

5.0 FIELD INSPECTION TECHNIQUES

Enforcement of emission standards for municipal incinerators must involve periodic inspections to ascertain the status of compliance on a continuing basis. An initial incinerator/emission control system inspection should precede any official compliance test program employing acceptable stack sampling. The purpose of this initial source inspection is to gather necessary pre-test information, to familiarize the inspector with the installation, operational and record keeping practices, to get to know the personnel and, if possible, to initiate certain procedures which will assist in future inspections. This inspection should follow a prescribed procedure with proper documentation as provided by a checklist.

The inspector should also be present during the official compliance tests to assure that representative operating conditions are maintained and that an acceptable operational and record-keeping practice has been properly established. Documentation of this activity should also be provided through a checklist.

Subsequent inspection visits should be scheduled and carried out on a regular basis. During such visits, the inspector should be prepared with an additional check-list which reflects the base-line information developed from the initial inspection and compliance test. Comparison of observed parameters with this baseline information, and inspection of records accumulated during the intervening period will allow the inspector to develop judgements as to potential changes in the compliance status and emission levels.

Aside from providing legally valid documentation and representing sound practice in any evaluation of a complex technical process, checklists can assure a consistency of approach from inspection to inspection. This is particularly critical in that the same inspector will not always be available for visits to the same installation. Accordingly, the balance of this Manual section will be largely devoted to the presentation and discussion of the use of the inspection checklists. Three such lists will be described:

- Initial source inspection
- Compliance test evaluation
- Periodic compliance inspection

Certain general technical considerations will first be discussed to aid inspection personnel in understanding the influence of process and control equipment parameters and their interaction on particulate matter emissions. Also, a discussion will be provided regarding process and control equipment instrumentation generally available, and its typical use. A similar discussion will be provided on record keeping practices.

5.1 Technical Considerations

5.1.1 Process Evaluation

Municipal incineration, as practiced in existing refractory-walled furnaces, many of which are more than ten years old, represents possibly one of the least sophisticated combustion processes in use today. Consequently, it is one of the most difficult applications for particulate matter emission controls. The performance of incinerator air pollution control equipment is strongly influenced by any number of variables of system operation - many of which are unpredictable. If any of these parameters deviate significantly from the conditions for which the control equipment was designed, emission standards may be exceeded, even in the case of the most sophisticated equipment such as electrostatic precipitators and high energy scrubbers.

The following are considered the most important operating parameters influencing particulate emissions:

- refuse composition
- refuse feed rate
- combustion air supply practice
- furnace temperature
- furnace draft
- gas cooling system performance
- general physical condition of installation

Refuse Composition

The heterogeneity of municipal refuse is well-known. Certain seasonal aspects can be predicted, and if an incinerator serves a fairly unchanging community, variations can be relatively minor. However, many unpredictable occurrences must be dealt with. For example, wet refuse when introduced into the incinerator, can cause depressed furnace temperatures, grate plugging, and uneven/improper airflow distribution resulting in poor or incomplete combustion and smoke. Large quantities of industrial or commercial wastes can cause excursions of furnace temperature, generally upward due to the unusually high heat content of certain components of the waste especially plastics. Often this is accompanied by the evolution of heavy smoke and particulate entrainment resulting from excessive turbulence over the burning bed. Generally, the operators' best remedy to the sudden arrival of such high BTU waste is to be aware of its presence and to adjust the system rationally either by reducing the burning rate, or by judicious mixing with other less potent waste.

Refuse Feed Rate

Municipal incinerators generally operate most effectively at a fixed burning rate. In most cases, deviation from this optimum rate, which is usually established over a long period of experimentation, results in conditions which promote increased particulate matter emissions. The more consistent and continuous the burning rate, the more trouble-free the operation of pollution control equipment. For this reason, batch type furnaces are far more difficult to control than continuously fed systems. Thus, non steady operation should be avoided, and control of changing refuse conditions is best effected by judicious mixing in the refuse pit.

Start up and occasionally shutdown or malfunction can promote greater than normal emissions of particulate matter. Start up must be accomplished slowly to protect refractory surfaces and grate components, and furnace temperatures must be intentionally controlled below the levels required for optimum combustion. Usually, the increased emissions are not noticeable since the incinerator is operating at a fraction of its full burning rate. The emissions can be increased on a weight per unit gas volume basis, but may be significantly lower than normal conditions, on a pound per hour basis. Shutdowns or malfunctions requiring shutdown are less likely to increase emissions since refuse charging is terminated and furnace temperatures are maintained by heat stored in the mass of the furnace refractory. The operator must adjust the combustion airflow downward, however, as the refuse burns down, or else high air input will quench the furnace temperature, promoting smoking and increased emissions.

Combustion Air Supply Practice

Combustion air is generally supplied from under the grate supporting the burning refuse in the form of underfire air, and above the grate in the form of overfire air. Both forms of air supply are extremely important to successful incinerator operation, however, underfire air rate is most associated with particulate matter emissions. Excessive underfire air supply usually results in particulate matter being lifted from the bed and entrained in the gas stream.

Excess air, representing the combustion air supplied to the burning process in excess of theoretical air, is generally the only parameter available to the operator to control furnace temperature, other than the burning rate. Additional air will quench the combustion gases and reduce temperature; reduced air supply would have the opposite effect. Depending on the nature of the refuse, the effects may reverse, however, with added air raising temperature and vice versa due to localized stoichiometric burning. Furnace excess air levels are generally maintained in the 100 - 200% range. These levels usually increase substantially at the emission discharge point due to air infiltration between the furnace and the stack. Values at the discharge could range from 350% to as high as 600% in poorly maintained or old units.

Furnace Temperature

Furnace exit gas temperature is one of the few operational parameters available to the incinerator operator which provides a "real-time" measure of the effectiveness of the process. In most installations the gas temperature is recorded continuously on charts, giving an operating history if the instrument and recorder are properly maintained. The location of the furnace exit gas temperature sensor varies, but generally, the thermocouple is found either at the discharge end of the secondary combustion chamber or just inside the entrance of the furnace exit duct. The thermocouple should be shielded to prevent flame radiation effects from biasing the gas temperature reading.

The variability in municipal refuse heating value and moisture content causes fluctuations in the combustion process, which are reflected most directly in variations in furnace exit gas temperature. The frequency and extent of such fluctuations can be a relative measure of how well the system is performing with respect to particulate matter emissions. Generally if the temperature is maintained between 1400°F and 1800°F, the operation can be considered satisfactory. Frequent and extensive excursions beyond these extremes can be expected to increase emissions, and should be avoided by operator intervention, either through combustion air adjustments, changes in burning rate, or refuse mixing.

Furnace Draft

Proper furnace draft is established through a balance of the airflows provided by the induced draft and combustion air fans. The result of this balance maintains the combustion chamber under slightly negative pressure (approximately 0.2 inches water column). This condition prevents the loss of combustion products from the furnace enclosure to the incinerator building (and consequently to the outside as fugitive emissions) by ensuring that all leakage is inward. If an incinerator furnace begins to exhibit "puffing" of combustion products from the furnace enclosure, the furnace draft is in all likelihood not being properly maintained. This can be indicative of poor combustion, generally attributable to an excessive charging or burning rate. The exhaust gas system is incapable of removing the combustion gases and only a reduction in the burning rate can restore a balanced draft.

Gas Cooling System Performance

The gas cooling system is designed to condition the furnace exhaust gases prior to entering the emission control components. Generally, water is sprayed into the hot gases to effect cooling by evaporation. In most existing systems the method of introduction of the water and the time allowed for evaporation to be completed are not adequate, and unevaporated water which drains to the bottom of the cooling chamber must be collected and either discarded or recirculated. This water will contain solid material which should be removed prior to recirculation. Recirculation, if not properly controlled, can cause a re-entrainment of particulate matter into the gas stream when the water is evaporated. The performance of the gas cooling system is critical to the performance of the emission control equipment, especially in the case of electrostatic precipitators, which cannot tolerate the carryover of liquid water droplets or excessive temperatures. Poor temperature control can adversely effect fly ash resistivity which has a critical influence on precipitator performance. Bag filter systems, although rarely used in incinerators, have an even narrower acceptable temperature range. Scrubber systems are more tolerant of gas cooling system aberrations, since further cooling to saturation is involved. Poor temperature control characteristics can be attributed to malfunctioning spray systems due to plugging, corrosion, etc. The plugging can be the direct result of improper recirculation and malfunctions of the wastewater (solids removal) system.

General Physical Condition of the Installation

The general physical condition of the incinerator installation can act as a yardstick by which an inspector can judge the probable performance of pollution control equipment. Poor housekeeping, leaks, corrosion, plugging, excessive temperature, etc. related to the burning system and gas handling components, could be an indication of potential problems with the pollution control equipment as well. Generally, a lack of concern or control over the major components of the system extends to the pollution control equipment components which are at least as complex and demanding of attention.

5.1.2 Pollution Control Equipment Evaluation

The inspector must be capable of evaluating the performance of a wide range of devices serving as pollution control equipment. These devices can range from simple settling chambers to complex electrostatic precipitator or scrubbing systems. Many of these control systems cannot meet specified emission limitations, others are of questionable performance and yet others do a superb job in meeting standards. It is the responsibility of the inspector to evaluate these systems with respect to their compliance with regulations on a continuing basis. The following will describe the observational and measurable characteristics by which the inspector can make judgements as to the probable level of performance of such pollution control equipment.

Settling/Spray Chambers

As previously mentioned, these are insufficient as control devices by themselves, especially with natural draft systems. They are capable of particulate removal efficiencies in the range of 20 to 50% by weight, at pressure drops of approximately 1/2 to 1 inch w.c. Their operation quickly departs from optimum due to poor water spray distribution, often brought about by plugging or corrosion of nozzles. This is a direct function of water recirculation practice which must involve some solids removal and pH control. The effectiveness of these systems can readily be gauged by observing the gas flow downstream of the sprays (viewing ports are generally available). If glowing "blackbirds" (relatively large flakes of unburned material - generally paper) are seen moving with the gas stream, then it is obvious that the spray system is not doing its job. In many cases the spray system is not responsive to furnace temperature excursions, except possibly by manual operator intervention.

Cyclones

Cyclones used in incinerator installations are generally of the large diameter, tangential entry type. The smaller diameter, "multi cyclone" installations have a tendency to plug, and are not generally favored. The larger diameter cyclones are limited to particulate removal efficiencies ranging from 60 to 75% by weight, when operated at pressure drops in the 3 to 5 inch w.c. range, which must be provided by an induced draft fan. Cyclones will generally not provide sufficient removal efficiency to meet existing regulations, although a few rare exceptions can be expected.

The maintenance of an adequate pressure drop across the cyclone is required in order for the efficiency to remain at the design level. When incinerator load is reduced, the exhaust gas volume will subsequently drop. Unless compensatory air is bled into the system, the cyclone pressure drop will decrease, causing collection efficiency to drop off. Pressure drops should be read from liquid manometer gauges which receive their signals through clean, dry and relatively straight tubing (free from sharp bends and kinks). The pressure taps should be true static taps, in that the protrusion of the tubing into the flowing gas stream should be minimized (a flush tap, free from burrs, is ideal). These taps should be located so that ash accumulations cannot cause plugging. The inspector should inspect the taps, tubing and manometers if access is provided. Pressure drops measured by indirect readouts such as magnahelic gauges should be viewed with caution. Recent calibration records for these devices should be obtained, if they are available.

Scrubbers

Scrubbers provide the most flexible form of air pollution control device in that improved performance can generally be obtained merely by increasing the power input to the system, usually without attendant physical changes. Scrubbers are capable of particulate matter collection efficiencies in the range of 80 to 99% by weight on municipal incinerators, with pressure drops ranging from 6 to over 25 inches w.c. They are more tolerant of variations in process conditions and do not require extremely stringent control of inlet temperature or moisture conditions. However, they do have attendant waste water treatment problems, which can affect performance, especially if water recirculation is practiced.

The two parameters of most interest in gauging scrubber performance are pressure drop and water consumption. There is usually a direct correlation between collection efficiency and pressure drops. The previous comments on pressure sensing manometers, lines, and taps apply here also, with an additional concern regarding liquid entrapment in the manometer tubing. The scrubber design will specify a certain liquid to gas ratio (gallons of scrubbing liquid per cubic foot of gas scrubbed) which must be maintained to assure a sufficient supply of liquid droplets for capture of particulates. Scrubber installations should incorporate either liquid flowmeters or liquid pressure gauges whose readings are calibrated against liquid flows. Recent calibration records should be obtained, if they are available.

If scrubber water is recirculated, a measure of water quality should be available to assure that the effective particulate loading to the scrubber is not being artificially increased by re-release of captured particulates. Periodic measurement of suspended solids in the recirculated water and subsequent comparison to design values should be incorporated. Similar control of the recirculated liquid pH should also be effected.

Electrostatic Precipitators

Electrostatic precipitators have perhaps been the most successful particulate emission control device applied to municipal incinerators. Collection of 90-99% by weight can be readily achieved. Pressure drops generally range between 3/4 to 1 1/2 inches w.c. and do not correlate with efficiency as is the case with cyclones and scrubbers. The precipitator must be isolated from the process variations inherent in incinerator operation. The temperature and moisture conditions entering the unit must be closely controlled to assure that particle resistivities remain in the optimum range. Wide variations in gas volume flow, resulting in subsequent variations in throughput velocity, can cause collected particles to become dislodged and be re-entrained in the gas stream. Flow distribution must be uniform across the precipitator entrance to prevent channeling and the associated increased velocities.

Voltage, current, sparking control and rapping cycle parameters are all established during the precipitator start-up period and should be maintained at those levels within allowable tolerances.

Baghouses (Fabric Filters)

Baghouses have not been widely applied to municipal incinerators, particularly existing installations since their performance is extremely sensitive to temperature extremes. The operational temperature range is very narrow, generally between 250 to 550°F; at higher temperatures, coatings on the glass filter bags deteriorate and precipitate rapid bag failure. At the low temperature extreme, the high moisture content of the exhaust gases combines with the collected particulate to plug and "blind" the bags. Maintaining operation within this narrow temperature range is considered extremely difficult in the incinerator environment and this accounts for the paucity of baghouse installations.

Operated properly, baghouses can achieve 99%+ collection efficiency, at pressure drops in the range of 6 to 10 inches w.c. The installation incorporates cleaning of the accumulated particulates from the bags by mechanical shaking or by reverse air pulsing. Pressure drop will be lowest immediately after cleaning, and highest just prior to cleaning. As with precipitators, cleaning cycle duration and frequency are established during initial operation and should be maintained at these values within specified tolerances.

General Physical Considerations

As inspector can obtain an impression of how well pollution control equipment has been performing by noting certain physical aspects of the installation which could be indicative of poor practice or malfunctions. He should be aware of the following:

- Evidence of leaks in ducts, flanges and around dampers or other openings which require seals, can indicate potentially upset flow patterns, unwanted gas cooling and excess air, additional pressure loss etc.

- Evidence of corrosion which can result in leakage and precipitate malfunctions in gas and liquid flow components.
- Evidence of plugging of gas and liquid flow passages, dust collector hoppers, etc. as a consequence of the high moisture content of the gas stream (for example hoppers which plug repeatedly may show signs of having been frequently pounded with hammers to loosen the plugging deposit).
- Evidence of large particle carryover, which can be indicative of buildup on duct/fan/control surfaces. Periodic loosening of these deposits and attendant high emissions can occur due to vibration, high gas velocity, etc.
- Evidence of excessive fan vibration due to an imbalance caused by material buildup on or corrosion of rotating surfaces.
- Evidence of excessive heating of control components (discoloration, etc.) which could indicate adverse temperature excursions, causing permanent damage to key components.

Visual observations of exhaust plume opacity can be indicative of poor combustion or inadequate pollution control. However, the inspector must be cautious in his evaluation since high levels of excess air and/or a steam plume tend to mask the real smoke density levels. Enforcement actions against municipal incinerators based on opacity violations are somewhat rare. A case built upon stack test results, application of emission factors and estimated control equipment efficiency levels, has been and will probably continue to be the mechanisms by which the compliance status of such units is determined.

Instrumentation/Records

Most existing incinerators do not provide a plethora of operational instrumentation or informative records. While some incinerators may initiate operation with an excellent complement of instruments, they are seldom maintained operational (generally because qualified instrument technicians are not available).

Burning rate is seldom a real-time factor in that it is based on truck scale weighing prior to discharge to the pit. There can be a lag time ranging from several hours to several days between refuse input measurement and actual burning. The determination of instantaneous burning rate, therefore, is usually accomplished by means of the subjective judgement and experience of the operators. A measure of furnace exit gas temperature is usually provided on a chart recorder. The operators generally strive to keep this instrument operational, in that it provides them with the only real-time gauge of the combustion process. After several months of operation using these temperature read-outs and manipulating grate speed, combustion air, and possibly mixing refuse in the pit, a diligent operator can come quite close to optimizing the operation. The inspector cannot expect to find available manually recorded readouts of the many operational variables at every incinerator installation. If possible, he should encourage operators to record such information, if it is not a current practice, in order to facilitate future inspections.

5.2 Inspection Checklists

The foregoing discussion provides the inspector with technical background on the application of air pollution control equipment to municipal incinerators; it also summarizes operational experience with such equipment, but does not provide a quantitative method for evaluating the equipment performance on a continuing basis.

In order to accomplish such evaluations, detailed checklists are necessary. These provide a thorough record of the condition of the equipment at each inspection and, by means of readily measurable parameters, give a quantitative indication of whether the design collection efficiency is being maintained.

Three checklists are presented in this section. The first is used at an initial inspection, that is, at the occasion of the first visit of enforcement personnel to the incinerator site. This checklist is designed to provide broad, baseline information on the incinerator operation and its pollution control equipment.

The second checklist is used at the time of an official compliance stack test, which may have been ordered as a result of the initial inspection.

The third checklist is used for subsequent periodic inspections, which will follow the initial inspection, and if ordered, the compliance test. This checklist will relate current operating parameters to those established as baseline information in the first two inspections.

5.2.1 Initial Inspection Checklist

Inspector Name & Title____________________
Date______________________________
File No____________________________

A. General:

1. Name of Facility____
2. Address____
3. Name of Plant Contact____________________________________
4. Source Code No.____
5. Age of Facility____
6. External Appearance (Comment on Stack Plume, Noise, Odor, Etc.)
   ____

B. Process Description (Attach Schematic Diagram)

1. Charging Method________ Batch________ Continuous
2. Furnace Type____
3. Grate Type____
4. No. of Furnaces________ Capacities (TPD)__________________
5. Furnace Grate Area(s)______________________________________
6. Furnace Draft__________ Natural__________ Induced
7. Pollution Control Equipment__________ Spray Chamber__________Cyclone
   __________ Scrubber__________ Electrostatic Precip.__________
   Bag Filter__________
8. Operating Schedule__________ Hr/Day__________ Days/wk__________ wk/yr
9. Actual Burning Rate (TPD)___________________________________
10. Auxiliary Burners?_______________ Fuel Type?_______________

C. Refuse Characteristics

1. Refuse Analysis (if available)________________________________
2. Composition Estimate (%'s)__________________________Residential,
   ______________________Commercial ______________________Industrial
3. Nature & Frequency of Industrial Waste__________________________
   ____
4. Refuse Variability____
   ____
5. Refuse Preparation Practices (give details)_____________________
   ____
   ____

D. Operational Factors

1. Nature & Frequency of Shut-Down/Startup Procedures____________________
____

2. Is Refuse Mixing in Pit Practiced?____________________________
____

3. Is there evidence of Furnace "Puffing"?______________________
____

4. Does operator modulate burning rate, combustion, air, and refuse mixture to optimize operation? (give details)____________________
____

5. Has this Incinerator been subject to frequent malfunctions?________

E. Emission Information

1. Has the Incinerator been subject to a particulate matter Emission Test within the last 3 years? (append copy of test report)__________
____

2. Test method used________ EPA Method 5_________ ASME
ASTM______________ Other ______________

3. What were the emission results?
______________ lb/hr
______________ lb/ton refuse
______________ grains/DSCF @ 12% CO_2
______________ lb/1000 lb gas @ 50% excess air

4. Applicable emission regulation______________________________
____

5. If no test has been conducted what are the estimated particulate emissions based on acceptable emission factors?
______________ emission factor (lb/ton)
______________ assumed burning rate (ton/hr)
______________ estimated uncontrolled emissions (lb/hr)
______________ assumed control efficiency
______________ estimated controlled emissions
______________ conversion of emissions to units of emission regulation (list assumptions)

F. Compliance Status (check one)

1. Facility never previously under any enforcement action_____
2. Facility presently out of compliance_____
3. Facility under notice of violation_____

4. Facility presently on a compliance schedule_____

5. Facility presently operating under a variance_____

6. Facility presently in compliance_____

7. Facility to be shutdown (give schedule)_____

8. Facility subject of neighborhood complaints_____

G. Physical Observations

1. Condition of equipment for refuse delivery and charging

____

2. Condition of burning components (grates, refractory, air supply, etc.)

____

3. Condition of residue handling components (quench, conveyor, etc.)____

____

4. Condition of gas cooling equipment (nozzles, water handling, distribution etc.)_____________________________________

5. Condition of air pollution control equipment______________________

____

5(a) Is there evidence of corrosion?____________________

5(b) Is there evidence of plugging?_____________________

5(c) Is there evidence of prior temperature excursion?__________

5(d) Is there evidence of liquid or air leaks?______________

6. Comment on general housekeeping practice ____________________

____

7. Comment on neighborhood image of operation____________________

____

8. Estimated plume opacity _____ Observation conditions (location, time, humidity, cloud cover . . .) ____________________________

____

H. Plant Records

1. Are satisfactory records available as to burning rate? (Give details)

____

____

2. Are satisfactory records available as to nature, duration and frequency of shutdowns, startups, malfunctions outages? (Give details)__________

____

____

3. Are chart records kept for furnace and pollution control equipment inlet temperatures?________________________________

____

4. If opacity monitors are installed, are chart records available?____

____

5. Has the plant available complete and up to date drawings and specifications for all operating equipment?______________________

____

____

I. Plant Instrumentation

1. Are instruments in satisfactory operating conditions (Give details)

____

____

2. Obtain readings for the following parameters if instruments are available or operational (Obtain charts if possible)

(a) Furnace exit gas temperature_____°F (Note location of sensor)
(b) APC device inlet temperature__________°F (Note location of sensor)
(c) Overfire air draft_____in. H_2O (Note location of sensor)
(d) Underfire air draft_____in. H_2O (Note location of sensor)
(e) Grate speed or equivalent_____ (Indicate units)
(f) Burning rate__________ Tons/hr
__________ (Indicate how obtained)
(g) Flue gas composition
O_2 _____% (Note location of sensor)
CO_2 _____% (Note location of sensor)
CO _____% (Note location of sensor)
(h) Emission opacity _____% (Note location of sensor)
(i) Precipitator spark rate__________ sparks/min
(j) Precipitator secondary voltage__________ kV (by section)
(k) Precipitator secondary current__________ mA (by section)
(l) Cyclone pressure drop__________ in H_2O (Note location of sensor)
(m) Scrubber pressure drop__________ in H_2O (Note location of sensor)
(n) Scrubber water rate__________ GPM (Note location of sensor)
(o) Spray chamber water rate__________ GPM (Note location of sensor)
(p) Fabric filter pressure drop__________ in H_2O (Note location of) (sensor)
(q) Precipitator rapping frequency__________ (by section)
(r) Fabric filter cleaning frequency__________ (by section)

(s) Water treatment system

Suspended solids concentration_________ mg/l

pH _________

(t) Recirculation percentage to scrubber and spray_________%

(u) Blowdown rate_________ GPM

J. Pre-Test Information

1. Will a particulate emission test be required to ascertain compliance?_________

2. Are sampling ports and platform in place?_________
   (a) Number of ports_________
   (b) Size of ports_________
   (c) Stack inside diameter at port level_________
   (d) Stack wall thickness at port level_________
   (e) Platform width_________ safe rails?_________ safe ladder?_________
   (f) Height of ports above ground_________ft.
   (g) Height of ports above breech entry_________ft.
   (h) Height of ports below stack exit_________ft.
   (i) If no ports or platform, height of stack available above breech entry_________ft.
   (j) If no ports, give information on variation of stack diameter with height_________

3. How will refuse burning rate be determined for emission test?
   (a) Pre-weighed refuse used only for test_________
   (b) Truck scales_________
   (c) Manual weighing_________
   (d) Sampling of craneloads and counting of loads_________

   ____

4. What is recommended elapsed time to be granted to facility to arrange for and complete emission test?_________

5. Will the facility be required to institute any record-keeping procedures preparatory to the test or future inspections?_________
   (a) Give detailed requirements (readings to be taken, frequency, data format, supervision needed, etc.)
   (b) If continuously recording instruments presently inoperative are to be reinstated, give schedule for such reinstatement.

(c) If new continuous monitors are to be purchased and installed, give schedule for such installations.

K. Post Inspection Communication

1. Will the facility be notified of the results of the inspection?_______
2. Are documentation letters required to confirm agreed upon details regarding test arrangements and instrumentation?______________________
3. Are official notices required in accordance with regulations?________
   Test plan?__________
4. Other parties to be informed
   __________ Test consultant
   __________ State agency
   __________ Local agency
   __________ Regional agency
   __________ EPA
   __________ Manufacturer of air pollution control equipment

L. Evaluation of Prior Emission Test (Inspector should obtain copy of test report and append to this checklist)

1. Were acceptable test procedures followed?____________________________
2. Were the tests conducted under the jurisdiction and approval of a regulatory agency?____
   ____
3. Were acceptable pre-test and test plan procedures followed?___________
   ____
4. Were the tests done for information only (as opposed to determining official compliance status)____
5. Is the testing firm well-known for satisfactory work?_________________
6. Were three satisfactory tests completed?______________________________
7. What were the resulting emission values________ ________ ________
   __________ (units)
8. Are there any significant differences from test to test (specify)?______
   ____
   ____
9. Are there any significant process differences between the time of the prior test and the present?____
   ____

10. Are the tests acceptable or not acceptable as baseline compliance status information (provide brief supporting discussion)____________

____

____

____

____

____

____

____

____

5.2.2 Compliance Test Evaluation Checklist

Inspector Name and Title________________
Date________________
File No.________________

A. General

1. Name of facility________________________
2. Address________________________
3. Name of plant contact________________________
4. Source code no.________________________
5. Age of facility________________________
6. Name of test firm________________________
7. Address________________________
8. Name of test firm contact________________________

B. Test Plan (Append copy to this checklist)

1. Has test plan been filed and approved?________________
2. Does test plan reflect agreements of pre-test discussion at time of initial inspection (or other visit)?________________
3. If test plan reflects differences have these been justified?________
   ____
4. Do all concerned parties have copies of test plan?____________
5. Has a pre-test conference to discuss the plan been held?________
6. Are all parties thoroughly familiar with the details of the plan?__
   ____

C. Incinerator Operating Conditions During Test

1. Will the refuse to be burned during the test be typical of normal operation?________________________
2. How has this been determined?________________________
   ____
3. Will refuse be preweighed?________________________
4. If not, how will burning rate be determined?________________
   ____
   ____
5. Is refuse moisture content satisfactory?________________
   ____
6. Have arrangements been made to communicate process variations to the test team?________________________

7. Will the incinerator be capable of sustained operation to allow for testing beyond the planned schedule in case of test malfunctions?

____

D. Test Equipment/Test Team

1. Is the testing organization well known to the inspecting agency?

____

2. Are they qualified?____________________________
3. Is their equipment of a satisfactory type and in good working order?

____

4. Have the data sheets been inspected at the beginning and completion of all tests?____________________________
5. Have sample acquisition and handling techniques been observed and found to be satisfactory?____________________________
6. Have nomograph settings been reviewed and found satisfactory?______
7. Have probe cleaning procedures been satisfactory?________________
8. Have post test calculations for isokinetic conditions shown satisfactory operation?____________________________
9. Has process coordination been satisfactory?____________________

____

____

E. Test Condition Data

1. Record location of sampling points with respect to breech entry and stack exit, if different from test plan________________________

____

2. Record length to diameter ratios associated with above____________

____

____

3. Record No. of sampling points (total and per port) required for above in accordance with EPA method 5______________________________

____

4. **Test Details**

Record values in accordance with the following Table as a check on the information to be obtained by the test team and as independent documentation. This should be done for all tests.

Test No.____________ Start Time____________ Finish Time____________

	Yes	No
Preliminary Traverse Run (Method 1) Chosen Nozzle Diameter_____in.	☐	☐
Train Leak Check	☐	☐
Moisture Determination (Method 4) Moisture Content_____% ml Collected/Gas Volume_____ml_____ft^3	☐	☐

Combustion Gas Analysis O_2_____%

CO_2_____%

CO_____%

Dry Gas Meter Reading Before Test_____ft^3 @__________(time)

Dry Gas Meter Reading After Test_____ft^3 @__________(time)

Volume Sampled _____ft^3

Test Duration________________________________minutes

Average of Meter Orifice Pressure Drop______________inches

Average Duct Temperature__________________________°F

Velocity Head at Sampling Point __________inches H_2O

Meter ΔH@* __________

Repetition Start Time __________

Repetition Finish Time __________

*Orifice pressure differential pumping 0.75 ft^3 of dry air at standard conditions.

F. Instrumentation Data

Record values in accordance with the following table, as a check on the information to be obtained by the test team, and as independent documentation

ITEM	UNITS	VALUES[a]				
Secondary Chamber Temp.	°F					
APC Device Entry Temp.	°F					
Overfire Air Draft	in. H_2O					
Underfire Air Draft	in. H_2O					
Grate Speed	indicate units					
Refuse Measuring Sensors	indicate units					
O_2	%					
CO_2	%					
CO	%					
Opacity Monitor	%					
Precipitator						
Spark Rate	sparks/min					
Secondary Voltage	kV					
Section No.						
Section No.						
Section No.						
Section No.						
Section No.						
Section No.						
Secondary Current	mA					
Section No.						
Section No.						
Section No.						
Section No.						
Section No.						
Section No.						
Scrubber						
Water Rate	gal./min					
Pressure Drop	in. H_2O					

[a] See Table 5-1 for recommended frequency of recorded values.

Table 5-1

Incinerator Operating Conditions Which Affect Emissions

Observation	Location	Comments
INCINERATOR		
Secondary chamber temperature	Control panel gage	Note thermocouple location in combustion chamber. Record values every 20 minutes
Flue gas concentration (CO_2, CO, O_2)	Control panel gage	
Underfire air draft	Control panel gage	Many incinerators do not monitor overfire and underfire air draft. Record every 20 minutes
Overfire air draft	Control panel gage	
Grate speed	Control panel gage	Record every 20 minutes
Crane weight sensors	Loading area	Record every 20 minutes
CONTROL DEVICE		
Control device entry temperature	Control panel gage	Record twice per performance test
Electrostatic precipitator		
Spark rate/section	Meter on precipitator control panel	Record twice per performance test
Voltage/section	Meter on precipitator control panel	Record twice per performance test
Current/section	Meter on precipitator control panel	Record twice per performance test
Scrubber		
Water rate	Ask operator	Record twice per performance test
Pressure drop	Control panel gage or manometer on scrubber	Record twice per performance test
Baghouse		
Pressure drop	Control panel gage	Record twice per performance test

5.2.3 Periodic Compliance Inspection Checklist

Inspector Name & Title________________

Date________________

File No________________

A. General:

1. Name of facility________________
2. Address________________
3. Name of plant contact________________
4. Source code no.________________
5. Age of facility________________
6. External Appearance (comment on stack plume, noise, odor, Etc.)________________

____

____

7. Give reference to previous inspections
   (a) Initial inspection date________ File no________
   (b) Source test inspection date________ File no________
   (c) Periodic inspection date(s) & File no's________

   ____

   ____

8. State compliance status as of last previous inspection________________

____

____

9. List record keeping requirements established by previous inspections and give evaluation (satisfactory - unsatisfactory)________________

____

____

____

10. List any pertinent information relative to changes in the impact of this operation on the surrounding community since the last inspection

____

____

B. Process Description (Attach Schematic Diagram)

1. Charging Method_______ Batch_______ Continuous
2. Furnace Type_ ____________________
3. Grate Type____________________
4. No. of Furnaces_______ Capacities (TPD)____________________
5. Furnace Grate Area(s)____________________
6. Furnace Draft_________ Natural_________ Induced
7. Pollution Control Equipment_________ Spray Chamber_________Cyclone

   _________ Scrubber_________ Electrostatic Precip._________

   Bag Filter_________
8. Operating Schedule_________ Hr/Day_________ Days/wk_________ wk/yr
9. Actual Burning Rate (TPD)____________________
10. Auxiliary Burners?_____________ Fuel Type?____________________

C. Refuse Characteristics

1. Refuse Analysis (if available)____________________
2. Composition Estimate (%'s)____________________Residential,

   ____________________Commercial ____________________Industrial
3. Nature & Frequency of Industrial Waste____________________

   ____
4. Refuse Variability____________________

   ____
5. Refuse Preparation Practices (give details)____________________

   ____

   ____

D. Operational Factors

1. Nature & Frequency of Shut-Down/Startup Procedures____________________

   ____
2. Is Refuse Mixing in Pit Practiced?____________________

   ____
3. Is there evidence of Furnace "Puffing"?____________________

   ____
4. Does operator modulate burning rate, combustion, air, and refuse mixture to optimize operation? (give details)____________________

   ____
5. Has this Incinerator been subject to frequent malfunctions?________

E. Physical Observations

1. Condition of equipment for refuse delivery and charging

____

2. Condition of burning components (grates, refractory, air supply, etc.)

____

3. Condition of residue handling components (quench, conveyor, etc.)_____

____

4. Condition of gas cooling equipment (nozzles, water handling, distribution etc.)______________________________________

5. Condition of air pollution control equipment__________________

____

5(a) Is there evidence of corrosion?_________________

5(b) Is there evidence of plugging?_________________

5(c) Is there evidence of prior temperature excursion?_________

5(d) Is there evidence of liquid or air leaks?___________

6. Comment on general housekeeping practice ________________

____

7. Comment on neighborhood image of operation________________

____

8. Estimated plume opacity ____________ Observation conditions (location, time, humidity, cloud cover . . .) ______________

____

F. Plant Records

1. Are satisfactory records available as to burning rate? (Give details)

____

____

2. Are satisfactory records available as to nature, duration and frequency of shutdowns, startups, malfunctions outages? (Give details)_________

____

____

3. Are chart records kept for furnace and pollution control equipment inlet temperatures?____________________________

____

4. If opacity monitors are installed, are chart records available?_____

____

5. **List and give details as to additional record keeping practice instituted since last previous inspection** ______________________

____

____

G. Control Equipment

1. Electrostatic Precipitator

Section					
Primary Current, amps					
Primary Voltage, volts					
Secondary Current, mA					
Second Voltage, kV					
Spark Rate, spk/min					

2. **Scrubber**

Module	
Liquid Flow, gal./min.	
Pressure Across Scrubber, in. H_2O	

3. **Fabric Filter**

Compartment	
Pressure Drop Across Fabric Filter, in. H_2O	

Additional Observations:

4. **CONTROL PANEL** **Time**______________

Secondary Chamber Temp. ______________°F

APC Device Entry Temp. ______________°F

Underfire Air Draft ______________in. H_2O

Overfire Air Draft ______________in. H_2O

O_2 Analyzer ______________%

CO_2 Analyzer ______________%

CO Analyzer ______________%

Grate Speed ______________(indicate units)

Refuse Measuring Sensors ______________(indicate units)

5. RECORDS

Temperature Charts (Dated and filed by Incinerator Personnel)

	Satisfactory	Unsatisfactory
Secondary Chamber	☐	☐
APC Device Entry Gas	☐	☐

Hours of Operation____________________

Charging Rate, T/hr____________________

Daily Collection, T/day________________

6.0 COMPLIANCE SCHEDULE DEVELOPMENT - BACKGROUND

6.1 General

The installation of pollution control equipment on an existing incinerator is but one option available to a municipality to meet the applicable emission limitations. The decision to install equipment is generally made after all the possible alternatives for solid waste disposal have been evaluated as to costs, availabilities, applicability, etc. Many municipalities choose to shut down their incinerator and opt for sanitary landfill operations because the costs of land and transportation are often less than those associated with upgrading and operating their present installation. However, in large, densely populated areas such as exist along the east coast of the U.S. (see Figure 2-1, Incinerator Belt), where land prices are extremely high, the costs associated with sanitary landfill operations are often greater than for incineration. In these cases, therefore, incinerator upgrading is likely to be the most economically attractive alternative to comply with air pollution regulations.

The purpose of this section of the Manual is to assist enforcement personnel in their development of an effective and reasonable compliance schedule for implementation by the incinerator owner. It is intended to apply to those situations where upgrading is the selected option for compliance. It does not address the use of any other solid waste management alternatives but the contents may assist the municipality in evaluating the upgrade option against other choices.

The Compliance Schedule is the means by which a regulatory agency specifies a timetable outlining the sequence of events required of a municipal incinerator owner to meet source emission limitations. It consists of many interrelated elements and is one of the major components of the overall decision and activity process followed by the municipality. Figure 6-1 outlines the elements of such an overall decision process.

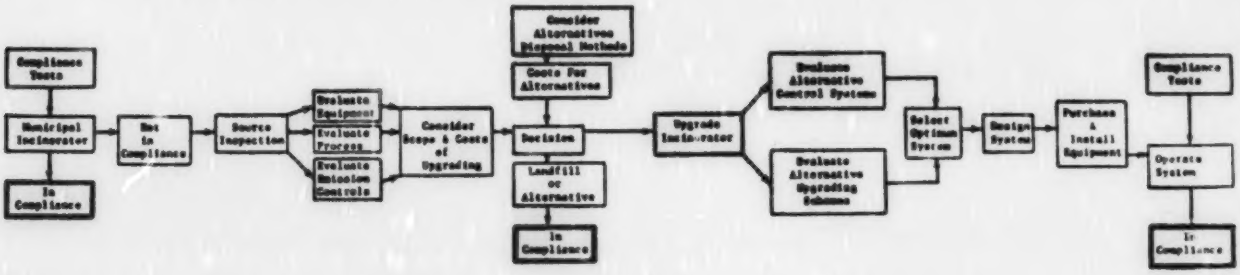

Compliance Tests
Municipal Incinerator
In Compliance
Not in Compliance
Source Inspection
Evaluate Equipment
Evaluate Process
Evaluate Emission Controls
Consider Scope & Costs of Upgrading
Consider Alternatives Disposal Methods
Costs For Alternatives
Decision
Landfill or Alternative
In Compliance
Upgrade Incinerator
Evaluate Alternative Control Systems
Evaluate Alternative Upgrading Schemes
Select Optimum System
Design System
Purchase & Install Equipment
Compliance Tests
Operate System
In Compliance

Figure 6-1

Elements of Municipality Decision Process
to Effect Incinerator Compliance

The spectrum of possible approaches for upgrading an existing municipal incinerator could include any or all of the following components:

(1) Improve refuse handling and charging to provide for more stable combustion

(2) Eliminate air flow leaks to reduce excess air and improve combustion

(3) Provide evaporative or convective cooling to reduce exhaust temperatures and permit installation of emission control equipment

(4) Install new or replace existing air pollution control systems (upgrading)

While the first two items would undoubtedly improve the operation of a municipal incinerator, they would not usually, in themselves, effect compliance. This Manual section will deal with upgrading to achieve major reductions in pollutant emissions and will consider the basic equipment as well as the ancillary items required for effective operation. The following items will be considered:

(1) Costs of gas cooling and air pollution control equipment

(2) Capabilities of vendors to supply and install control systems

(3) The time required to acquire and install control systems

(4) The methods used by municipalities to fund incinerator upgrading projects

6.2 Air Pollution Control Equipment Costs

6.2.1 Basis of Analysis

In order for municipalities to objectively evaluate the alternatives open to them for upgrading existing municipal incinerators, those alternatives must be described in terms of their costs, both for the initial purchase and for their annual owning and operating charges. As discussed previously, present particulate matter emission regulations for existing incinerators are sufficiently stringent to preclude the use of rudimentary particulate matter collection equipment such as settling chambers and cyclones. Only the more sophisticated high energy scrubbers and electrostatic precipitators can be employed to achieve current or expected standards which would require at least a 90% collection efficiency, however most State regulations require even higher efficiencies. Thus, the cost analyses which follow are restricted to consideration of high energy scrubbers and electrostatic precipitators only. Although baghouses are generally included in discussions of high efficiency particulate matter collection equipment, they have not been successfully applied on municipal incinerators, and are not expected to be a factor in future upgrading projects. Thus, they have not been included in the analyses of costs to be presented.

Size Considerations

Since the cost of particulate control equipment is a function of the gas volume flow to be treated, cost relationships have been developed on that basis. For existing municipal incinerators, the quantity of flue gases generated is not only related to the refuse burning capacity of the unit but also to several other factors, the most significant of which is excess air. Existing units, however, exhibit a wide range of excess air levels. This variability is the result of the deliberate as well as the casual, uncontrolled introduction of airflow into the furnace. As the amount of excess air increases, the total exhaust gas volume to be treated increases. This in turn dictates the use of larger fans, and bigger ducts with increased energy requirements, causing total emission control system costs to escalate.

Other factors that influence the volume flow to be handled by control equipment include refuse composition, furnace discharge temperature, and the quantity of quench water which must be evaporated to reduce exhaust temperature.

In order to reduce these requirements to a common basis for comparison, Figure 6-2 has been prepared. The values presented are based on the combustion of municipal refuse whose average heating value was assumed to be 4400 BTU/ pound. A range of excess air levels is presented for both refractory lined furnaces and units utilizing heat removal through water walls or waste heat boilers. The gases leaving the furnace have been cooled to 500°F for compatibility of analysis. For the case of refractory walled furnaces, this cooling is accomplished by introduction of evaporative cooling water in the amount of 2.0 to 2.6 pounds per pound of refuse, depending on the furnace exit temperature, which can vary from 1760°F to 1300°F for the range of conditions shown (100% to 200% excess air). The requirement for this evaporative cooling accounts for the higher total exhaust gas flows for refractory units.

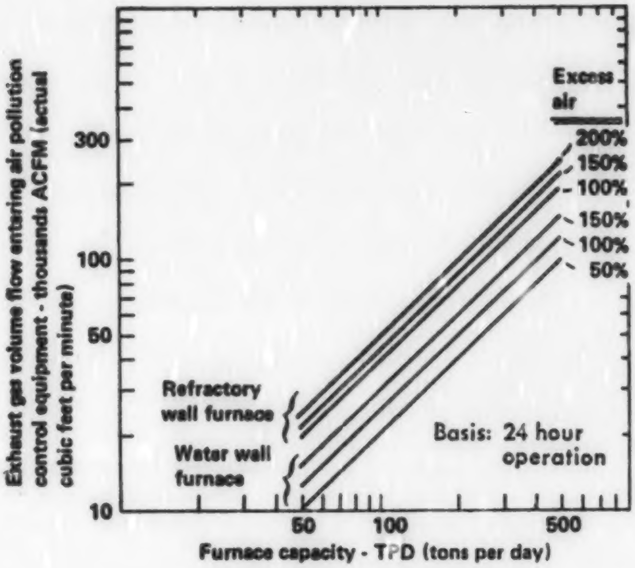


Fig. 6-2.

Municipal incinerator exhaust gas flow rates (ACFM) vs. furnace capacity (TPD) for refuse with HHV of 4400 Btu/lb and at 500° F temperature entering air pollution control equipment.

500° F reached by water spray for refractory wall furnace; 2.0 - 2.6 lb H_2O/lb refuse.

500° F reached by convective cooling for water wall furnace; 0 lb H_2O/lb refuse.

It should be understood that the values presented in Figure 6-2 will differ significantly for other refuse compositions or heating values and for values of control equipment inlet temperature other than 500°F. For that reason, Figures 6-3 and 6-4 have been developed. Figure 6-3 shows the effect of changes in refuse heating value on the total exhaust gas flow generated. Figure 6-4 similarly shows the effects of different cooling rates on the total gas flow. Thus, by applying the information presented in these three figures, furnace design/operating conditions and characteristics may be translated into the required size of the particulate emission control equipment. Once this information has been generated, an estimate of total system capital and operating costs may be determined.

Efficiency Considerations

In order to meet the majority of present and anticipated emission limitations for particulate matter, collection efficiencies of at least 90% must be achieved. Some states and NSPS, however, require efficiencies

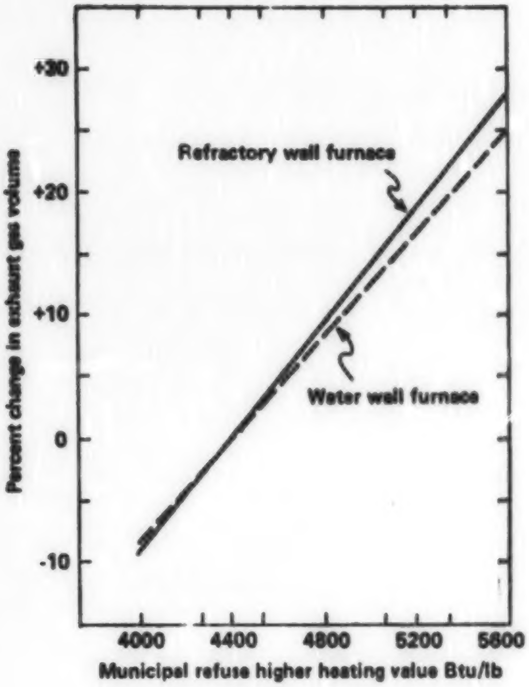


Figure 6-3

Variation of Municipal Incinerator Exhaust Gas Flow Rates (%) vs. Refuse Heating Value at 500° F (Temperature entering air pollution control equipment. 4400 Btu/lb is nominal heating value. Relationship is independent of excess air value. Ref. Figure 6-1)

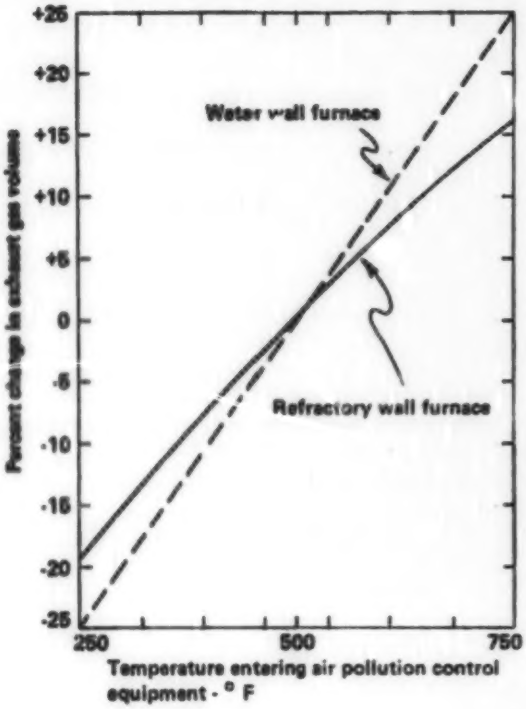


Figure 6-4

Variation of Municipal Incinerator Exhaust Gas Flow Rates (%) vs. Temperature entering Air Pollution Control Equipment (Relationship is independent of excess air value and refuse heating value. Ref. Figure 6-1. Temperatures are reached for refractory wall furnace by water spray and for water wall furnace by convective cooling)

in the mid to upper nineties in order to meet the appropriate emission limitations. Cost relationships have therefore been developed for efficiencies ranging from 90% to 99%. In general, increased efficiency requirements demand increased expenditures for electrostatic precipitators; improved efficiencies generally relate to initial purchase cost because more effective particle capture requires additional collector plate area and overall unit volume to provide sufficient residence time for the particles to be captured. Scrubbers on the other hand, achieve improved efficiencies by increasing the power expended in bringing the liquid and the particles to be captured into intimate contact, and this can often be achieved with little or no physical change to the system. Thus, increases in scrubber efficiency generally require increases in operating costs.

The cost curves which follow relate the total installed and annual owning and operating costs of electrostatic precipitators and scrubbers to the exhaust gas volume flow rate which must be treated. Annualized cost relationships have been presented on the basis of annual operating hours since this appears to be the most significant variable. The cost curves are presented for three values of precipitator efficiency - 90%, 95%, and 99%, and four values of scrubber pressure drop - 10, 15, 20 and 25 inches w.c., corresponding to 90, 94, 96 and 97 1/2% efficiency.

Gas Cooling Considerations

A temperature of 500°F was chosen to be representative of the general range of inlet conditions required for electrostatic precipitators (approximately 400 to 600°F). Since scrubbers generally continue the cooling process to saturation conditions, the inlet temperature can be substantially higher than 500°F. In some cases, scrubbers whose inlets are refractory lined can accept gases directly from the furnace and accomplish the gas cooling in a single unit. In other cases, some fraction of the gas cooling process must be accomplished prior to scrubbing.

Gas cooling for precipitators or scrubbers involves the use of either a gas quenching chamber or a waste heat boiler. When applied to precipitators, the quenching chamber must be carefully designed and operated to prevent the carryover of liquid water droplets which can cause operational malfunctions and damage. For scrubbers, however, this requirement is not critical. Waste heat boilers accomplish the cooling of the gases without addition of either quench water or dilution air to produce steam or hot water from which energy may be extracted. If energy is not extracted, the heat must be dissipated either by "blowing" steam to the atmosphere or through the use of a condenser and a cooling tower.

In general, it is unlikely that waste heat boilers would be installed to achieve gas cooling on existing incinerators unless the steam produced is highly marketable and offers significant advantages over conventional means of steam production. However, this means of cooling does offer an alternative to the gas quenching chamber, and may be feasible in selected installations.

Total installed cost relationships have been developed for gas quenching chambers and waste heat boilers as a function of capacity expressed in terms of exhaust volume flow.

6.2.2 Capital Costs

Gas Conditioning Equipment

Capital costs including installation for quenching chamber and waste heat boiler gas conditioning systems are presented on Figure 6-5. Values have been normalized on the basis of dollars per actual cubic foot per minute of gas and are presented as a function of the system capacity in actual cubic feet per minute. These capital cost estimates incorporate all the following auxillary components for both systems:

- Pumps
- Piping
- Temperature Controls
- Ductwork

The quenching chamber system utilizing fine sprays as the delivery mechanism exhibits about a 3:1 spread in capital costs over the range of system capacities presented. This wide range reflects an economy of scale since the cooling chamber shell costs do not increase in direct proportion to system capacity. The waste heat boiler on the other hand exhibits a

2:1 cost spread over the same size range but is about an order of magnitude more expensive than the cooling chamber. The use of a waste heat boiler does, however, provide the opportunity for generating steam which could be sold to offset operating costs if an adequate market for the steam is available.

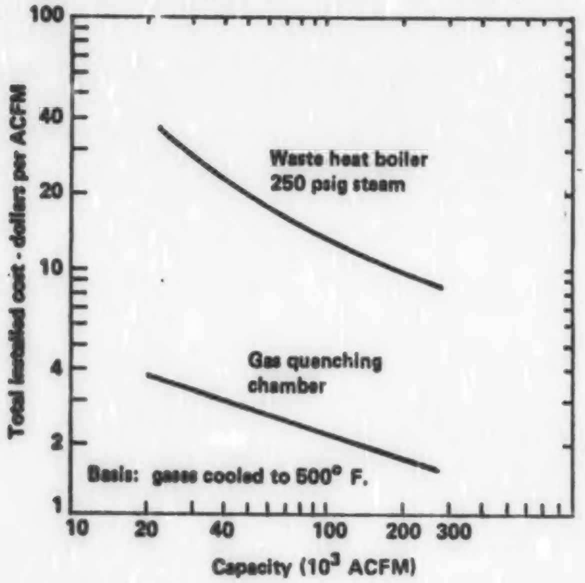


Figure 6-5

Air Pollution Control Systems total Installed Costs for Gas Quenching Chamber and Waste Heat Boiler

Emission Control Equipment

Capital costs including installation for electrostatic precipitator control systems are presented in Figure 6-6. Values have been normalized on the basis of dollars per actual cubic foot per minute of gas treated and are presented as a function of system capacity in cubic feet per minute. Total installation system costs are based on installation costs of $2 for each dollar of basic equipment cost. Cost relationships have been developed for three efficiency levels - 90%, 95% and 99%. The high efficiency system results in significant additional costs over the lower efficiency systems due to the relationship between efficiency and collection plate area, associated electrical components and overall collector volume. These capital cost estimates incorporate all auxiliary components such as:

- Fans/motors
- Ductwork and valves
- Electrical components
- Associated system controls
- Particulate collection and disposal features

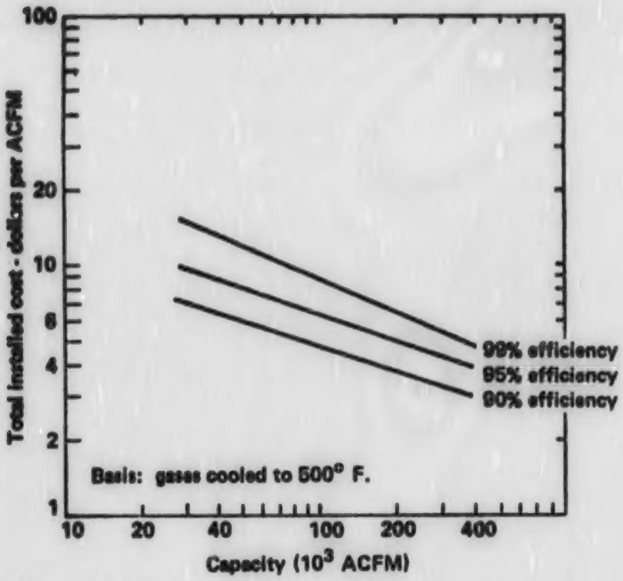


Figure 6-6

Air Pollution Control Systems Total Installed Costs
Electrostatic Brecipitators

Capital costs, including installation, for venturi scrubber control systems are presented in Figure 6-7. The values are expressed as a function of four pressure drop levels - 10, 15, 20 and 25 inches of water column. These pressure drops, when applied to "typical" municipal incinerator fly ash, result in collection efficiencies of about 90%, 94%, 96% and 97 1/2% by weight (See Figure 4-2). The cost estimates incorporate auxiliary components such as:

- Pumps
- Nozzles
- Piping
- Water treatment and recirculation components
- Fans/motors
- Ductwork and valves
- Structural components

Total installed system costs are based on installation costs ranging from $1.50 to $4 for each dollar of basic equipment cost depending upon scrubber efficiency.

Only slight differences in installed cost are noted attributable largely to fan and motor costs, since little change in physical size of the units is necessary to accommodate the increases in pressure drop. There are, however, significant differences in operating costs.

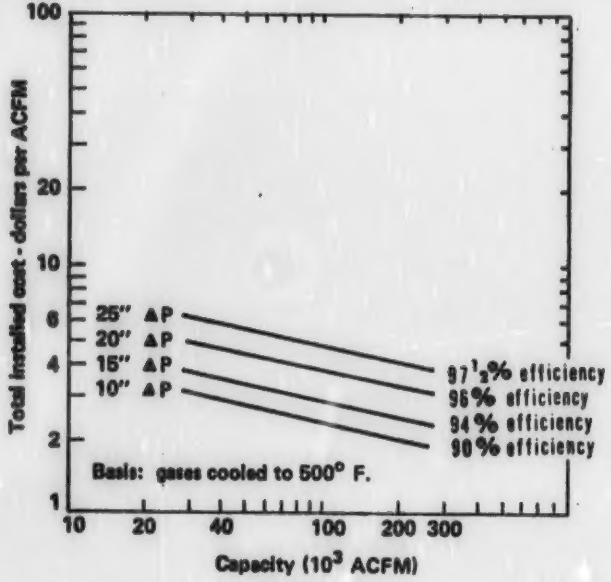


Figure 6-7

Air Pollution Control Systems Total Installed Costs
Venturi Scrubbers

6.2.3 Annualized Operating Costs

Gas Conditioning Equipment

Annual operating costs for gas quenching chamber and waste heat boiler gas conditioning systems are described on Figures 6-8 and 6-9. The dollar values are presented as a function of unit capacity in actual cubic feet per minute as determined at the outlet of the conditioning system.

The annualized costs have been developed on the basis of reducing the exhaust gas temperature from 1800°F to 500°F and include the following basic factors:

- Electrical and water costs (primarily for pumping)
- Maintenance costs
- Amortization and interest

For a given capital investment, the last cost element is fixed, whereas the first two are dependent upon hours of operation. Figures 6-8 and 6-9 show the cost relationships for both types of conditioning systems for one, two and three shifts of operation, corresponding to 2000, 4000 and 6000 annual operating hours. Note that the annualized costs associated with a waste heat boiler is four to eight times greater than the corresponding costs for a quench chamber. This is the result of the higher capital cost payback entailed in a waste heat boiler system. The curves on Figure 6-9 do not reflect the potential savings which could be realized if the steam produced were marketed.

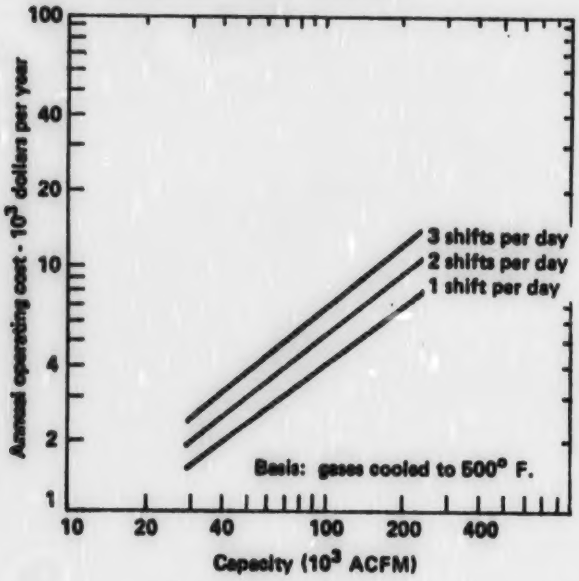


Figure 6-8

Air Pollution Control Systems
Annual Operating Costs
Gas-Quenching Chamber

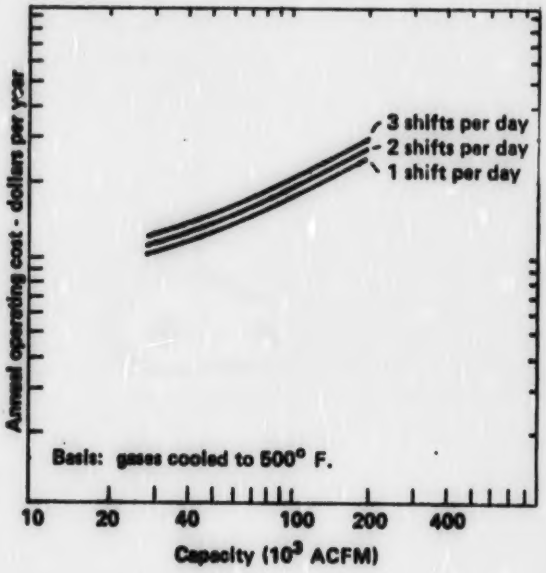


Figure 6-9

Air Polluation Control Systems
Annual Operating Costs
Waste Heat Boiler

Emission Control Equipment

Annual operating costs for electrostatic precipitator control systems are shown in Figure 6-10. The dollar values are presented as a function of unit capacity in actual cubic feet per minute, and for three levels of precipitator efficiency ranging from 90% to 99% by weight collection efficiency. The effect of annual operating hours on the cost relationship is also illustrated. The basic cost elements include electrical, water, maintenance and amortization costs. Note that for a given unit size, dollar values appear to be relatively insensitive to the number of system operating hours. This is due to the predominating effect of the fixed annual costs associated with capital payback for this type of system. The higher annual cost of the 99% unit over that of the 90% precipitator is also due largely to the difference in these fixed charges.

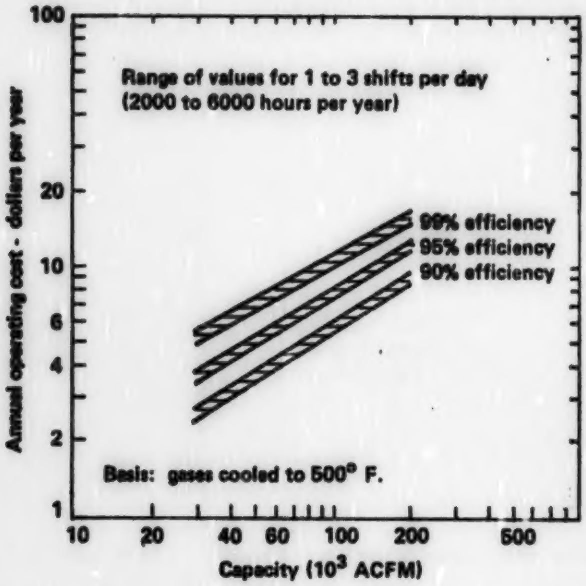


Figure 6-10
Air Pollution Control Systems Annual Operating Costs
Electrostatic Precipitator

Figure 6-11 presents operating cost information for venturi scrubber control systems. Four categories of scrubbers are shown, providing collection efficiencies of approximately 90, 94, 96 and 97½%, by means of 10, 15, 20 and 25 inches water column pressure drops across the venturi throat. Again the effects of one, two and three shift operating schedules are illustrated. It is apparent that the scrubber systems are more sensitive to hours of operation than precipitators due to the large power costs.

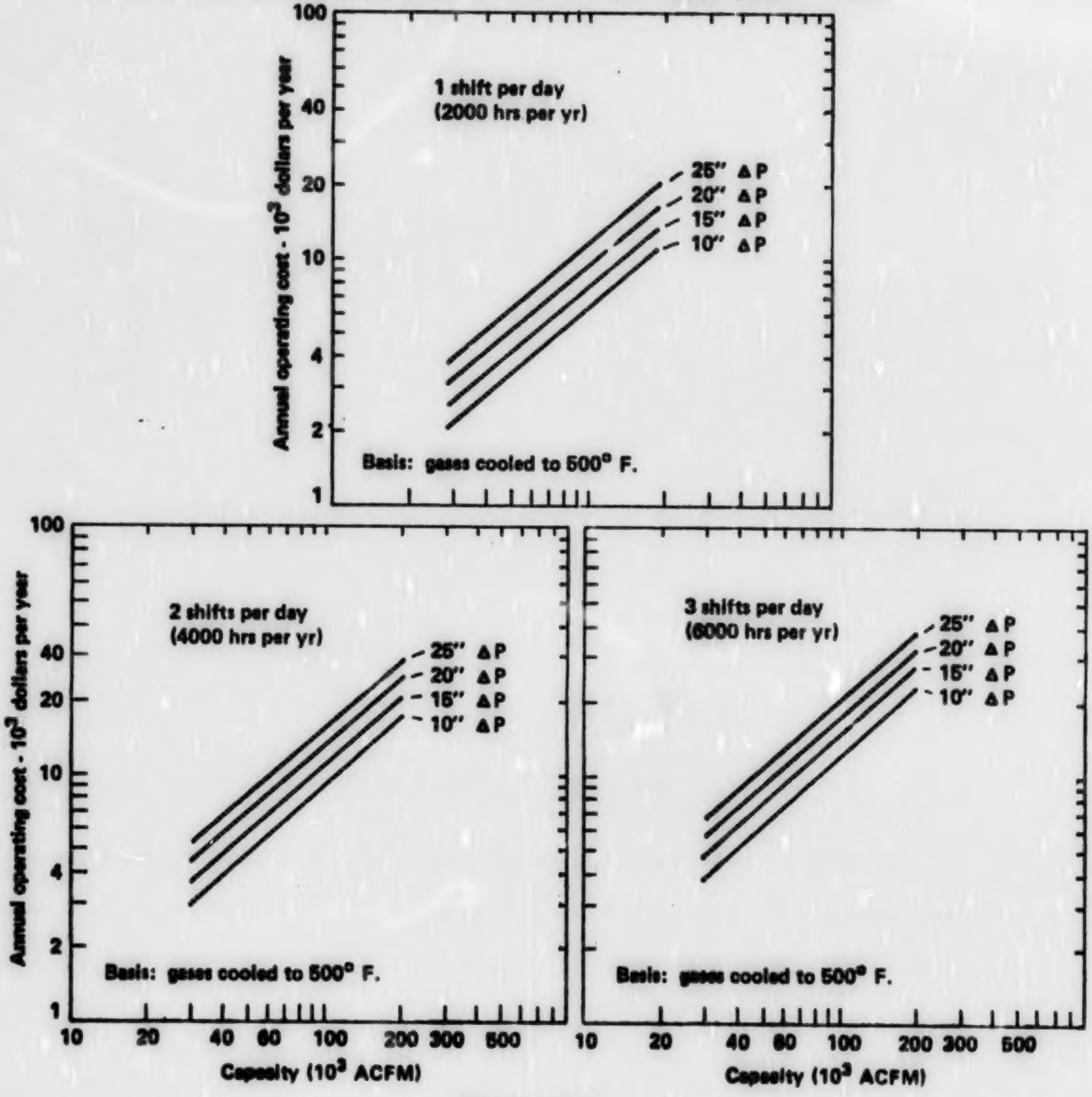


Figure 6-11

Air Pollution Control Systems Annual Operating Costs
Venturi Scrubber

The annual costs associated with owning and operating pollution control equipment can be significant. Tables 6-1 and 6-2 have been prepared to outline the extent of such costs for both a scrubber and a precipitator system, respectively, installed on a 100 and a 500 TPD incinerator. Total (operating and amortization) annual costs and costs normalized to $/ton of refuse charged are presented for a variety of collection efficiencies and operational schedules.

Plant Capacity (TPD)	Shifts Per Day	Pressure Drop ("H_2O)	Efficiency (%)	Annual Costs	
				Total ($/yr)	Normalized Total ($/ton of refuse)
100	1	10	90	29,000	1.16
		15	94	35,000	1.40
		25	97 1/2	52,500	2.10
	2	10	90	42,000	1.68
		15	94	51,500	2.06
		25	97 1/2	72,000	2.88
	3	10	90	55,000	2.20
		15	94	78,000	3.12
		25	97 1/2	94,000	3.76
500	1	10	90	112,000	0.90
		15	94	140,000	1.12
		25	97 1/2	210,000	1.68
	2	10	90	185,000	1.48
		15	94	225,000	1.80
		25	97 1/2	310,000	2.48
	3	10	90	245,000	1.96
		15	94	300,000	2.40
		25	97 1/2	410,000	3.28

Table 6-1

Summary of Annualized Costs
Venturi Scrubber

Plant Capacity (TPD)	Shifts Per Day	Efficiency (%)	Annual Costs	
			Total $/yr	Normalized Total ($/ton of refuse)
100	1	90	50,000	2.00
		95	63,000	2.52
		99	81,000	3.24
	2	90	58,000	2.32
		95	71,000	2.84
		99	90,000	3.60
	3	90	66,000	2.64
		95	80,000	3.20
		99	100,000	4.00
500	1	90	160,000	1.28
		95	188,000	1.50
		99	225,000	1.80
	2	90	192,000	1.54
		95	221,000	1.77
		99	261,000	2.09
	3	90	225,000	1.80
		95	260,000	2.08
		99	300,000	2.40

Table 6-2

Summary of Annualized Costs
Electrostatic Precipitator

Assumptions

(1) 150% excess air
(2) Gas volume
  43,000 ACFM for 100 TPD facility
  215,000 ACFM for 500 TPD facility
(3) Control device inlet temperature of 500°F
(4) Amoritzation: 6.67%/year (15 year life)

It must be understood, however, that these are only typical examples. Many situations could alter costs significantly. All assumptions and details of the calculations to develop annualized costs can be found in the "Documentation Report for Municipal Incinerator Enforcement Manual".

6.3 Vendor Capabilities

6.3.1 Regulatory & Enforcement Trends

Existing regulations which govern the emission of particulate matter from incinerators constructed before the effective date of New Source Performance Standards (NSPS) are being more rigorously enforced. The inability of some of these incinerators to comply with regulations is being documented by stack emission tests, and where appropriate, the cognizant regulatory agencies are developing compliance schedules for these sources. In many cases, the age of the facility and the costs associated with upgrading to meet emission standards have combined to achieve compliance by shutdown and the subsequent use of landfilling as the ultimate disposal method. However, others will choose to upgrade their facility in order to meet the applicable regulations. The potential for a large number of upgrading projects raises the question of whether the suppliers of air pollution control equipment can produce and install the necessary units over the short period of time likely to be involved, in view of their already heavy commitments to other industrial segments.

6.3.2 Demands on Equipment Suppliers

The statistics developed on the compliance status and projected compliance activity for existing municipal incinerators (see Section 2.0) indicate that there are likely to be 23 upgrading projects, scheduled for completion over approximately the next three years. Of these projects, it is estimated that 18 will utilize electrostatic precipitator control systems and 5 will utilize scrubber systems. The unit sizes could range from approximately 65,000 to 430,000 ACFM, with an aggregate installed cost of about $18 million. There are approximately a dozen qualified suppliers of electrostatic precipitators and several dozen qualified suppliers of scrubbing systems in the United States. Surveys of about half of the precipitator suppliers and several of the scrubber vendors were conducted. These contacts have provided assurances that the projected rate of orders they are likely to receive from incinerator upgrading activity will represent less than 10% of their total capacity to supply such systems over the time period involved. All agreed that this would not represent undue pressure on their design and fabrication facilities.

6.3.3 Conclusion

Upgrading of existing incinerators will occur in selected cases, depending upon location, age, size and other characteristics of a facility and its surrounding area. The number of such upgradings is not projected to be excessive and the associated demand on air pollution control equipment manufacturing capability will not cause difficulty for suppliers.

6.4 Time Tables/Schedules

6.4.1 Elements of Compliance Schedule

In order for a regulatory agency to develop a compliance schedule which can be readily kept under surveillance and which can be subjected to corrective action if needed, a sufficient number of schedule elements must be identified. A compliance schedule for upgrading an existing municipal incinerator should contain, at a minimum, the following elements:

- Preliminary investigation *
- Source tests *
- Evaluate control alternatives *
- Commit funds for total program *

- Prepare preliminary control plan and compliance schedule for agency
- Agency review and approval
- Finalize plans and specifications
- Procure control device bids
- Evaluate control device bids
- Award control device contract
- Vendor preparation of assembly drawings
- Review and approve assembly drawings
- Vendor preparation of fabrication drawings
- Fabricate control device
- Prepare engineering drawings
- Procure construction bids
- Evaluate construction bids
- Award construction contract
- Initiate on-site construction
- Install control device
- Complete construction (system tie-in)
- Startup, shakedown, preliminary source test
- Conduct final compliance test.

Items marked with an asterisk (*) may have occurred prior to the development and initiation of a compliance schedule.

Typically, the activities involved in finalizing fabrication drawings and the equipment fabrication will require the longest elapsed time period. In some cases preparation of drawings for and completion of site construction can require even longer periods.

Delays in achieving compliance schedule milestones can be attributable to any of the following:

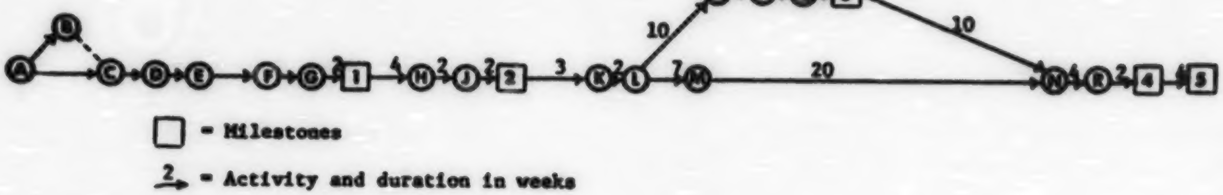
- Finalizing designs/drawings
- Inability of suppliers to obtain raw materials
- Inability of suppliers to obtain auxillary hardware
- Inability of the municipality to complete site preparation

Often these delays are unavoidable and beyond the control of the operator or supplier, but equally as often, delays can be attributed to inadequate project management and an unwillingness on the part of the municipality to press suppliers to meet commitments and deadlines. The enforcement agency can serve as a strong catalyst in detecting and correcting these situations.

6.4.2 Typical Compliance Schedules

Figures 6-12 and 6-13 present typical compliance schedules for the installation, respectively, of a scrubber and an electrostatic precipitator on a municipal incinerator. These schedules show elapsed time estimates for the activities occurring after the regulatory agency has approved the compliance program. Note that most activities involving the precipitator installation require up to twice the elapsed time needed for the scrubber. This is to be expected since the precipitator installation is more complex. For example, the period required to award the control device contact is 19 weeks for the precipitator and 10 weeks for the scrubber. Fabrication time is 40 weeks for the precipitator as opposed to only 20 weeks for the scrubber system. This results in the total elapsed time to completed installation of the equipment of 95 weeks and 50 weeks. Note that the site construction activity for the scrubber represents the critical path while equipment fabrication for the precipitator is the pacing item.

These are typical values, not representing any specific installation and should be treated as examples only. Each installation will exhibit its own peculiarities which will influence the overall schedules.



MILESTONES

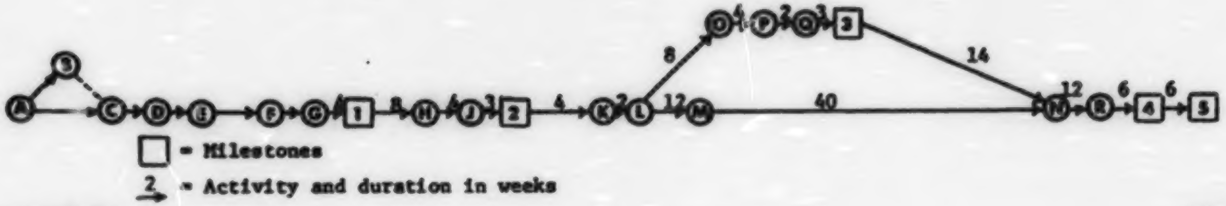
		ELAPSED TIME (WEEKS)
1	Date of submittal of final control plan to appropriate agency.	2
2	Date of award of control device contract.	10
3	Date of initiation of on-site construction or installation of emission control equipment	34
4	Date by which on-site construction or installation of emission control equipment is completed.	50
5	Date by which final compliance is achieved.	54

ACTIVITIES

Designation		Designation	
A C	Preliminary investigation	K-L	Review and approval of assembly drawings
A B	Source tests	L-M	Vendor prepares fabrication drawings
C D	Evaluate control alternatives	M-N	Fabricate control device
D E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare preliminary control plan and compliance schedule for agency	O-P	Procure construction bids
F G	Agency review and approval	P-Q	Evaluate construction bids
G-1	Finalize plans and specifications	Q-3	Award construction contract
1-H	Procure control device bids	3-N	On-site construction
H-J	Evaluate control device bids	N-R	Install control device
J-2	Award control device contract	R-4	Complete construction (system tie-in)
2-K	Vendor prepares assembly drawings	4-5	Startup, shakedown, preliminary source test

Figure 6-12

Schedule for Installation of a Wet Scrubber for Particulate Pollutant Control on a Municipal Incinerator



MILESTONES		ELAPSED TIME (WEEKS)
1	Date of submittal of final control plan to appropriate agency.	4
2	Date of award of control device contract.	19
3	Date of initiation of on-site construction or installation of emission control equipment.	42
4	Date by which on-site construction or installation of emission control equipment is completed.	95
5	Date by which final compliance is achieved.	101

ACTIVITIES

Designation		Designation	
A-C	Preliminary investigation	K-L	Review and approval of assembly drawings
A-B	Source tests	L-M	Vendor prepares fabrication drawings
C-D	Evaluate control alternatives	M-N	Fabricate control device
D-E	Commit funds for total program	L-O	Prepare engineering drawings
E-F	Prepare preliminary control plan and compliance schedule for agency	O-P	Procure construction bids
		P-Q	Evaluate construction bids
F-G	Agency review and approval	Q-3	Award construction contract
G-I	Finalize plans and specifications	3-N	On-site construction
I-H	Procure control device bids	N-R	Install control device
H-J	Evaluate control device bids	R-4	Complete construction (system tie-in)
J-2	Award control device contract	4-5	Startup, shakedown, preliminary source test
2-K	Vendor prepares assembly drawings		

Figure 6-13

Schedule for Installation of an Electrostatic Precipitator for Particulate Pollutant Control on a Municipal Incinerator

Additionally, these schedules assume single shift work efforts for fabrication and installation. For certain cases, however, enforcement officials may require multi-shift efforts to complete the project in the most expeditious manner.

6.4.3 Input From Equipment Suppliers

Contacts with suppliers of scrubbers and precipitators tend to confirm the typical elapsed times given in Figures 6-12 and 6-13 for completion of drawings and fabrication. The suppliers also emphasize the individuality of each installation, and that unpredictable delays can and do occur. In general the suppliers feel that the procurement periods have lengthened somewhat over the last few years and may continue to do so. In particular, suppliers can have difficulties dealing with municipalities, especially with regard to timely receipt of progress payments, excessively delayed final payments, etc. These problems can result in the devleopment of an overly cautious attitude on the part of the supplier and the subsequent slowing down of progress. If the enforcement agency remains alert to the potential for these difficulties, it may be possible to avert them by judicious mediation.

6.4.4 Conclusion

It is difficult to offer any conclusions regarding the likely trends in length of compliance schedules for upgrading municipal incinerators because of the special features inherent in each installation. Some delays can be associated with historical difficulties of suppliers dealing with municipalities; delays in engineering and fabrication are mostly the result of poor management, and in some cases, bad luck. No single remedy can be suggested, except that the enforcement agency can play a significant role in "keeping things moving."

There is one aspect of scheduling an upgrading program which can be a critically delaying factor, and which is usually out of the hands of the enforcement agency. This is the question of municipal funding practice which will be discussed in Section 6.5.

6.5 Municipal Funding Practices

The requirement for funding a multi-million dollar pollution control equipment installation has strong community tax rate repercussions. This frequently involves many lengthy hearings, referendums and town meetings during which time the upgrading program can only proceed through the preliminary engineering phase. The purpose of this section is to review the various means by which a municipality can fund pollution control equipment. The alternative financing methods introduced should be used only as general guidance. The specific method of funding is dependent on the characteristics of the procurement and the type of contract negotiated.

Local governments may draw capital for equipment from two sources: current revenues and borrowings. Current revenue, or capital budget financing requires full payment upon delivery. This mechanism is simple and involves few institutional or legal arrangements, however it is dependent upon the community's ability to raise surplus capital. Borrowings are the issuance of municipal bonds and notes, or bank loans. Borrowings are divided into short term options (1-5 years - less than $500,000 capital required), medium term options (5 to 10 years - $500,000 to $1,000,000), and long term options (10 to 30 years - over $500,000). If a municipality cannot raise surplus capital, short and medium term financing places a heavy drain on government cash flow.

6.5.1 Short-Term Options

Financial options available to municipalities on amounts less than $500,000 are the use of capital budget allocations, funds from previously authorized general obligation (GO) bonds, notes, and bank borrowing. Capital budget allocation and the use of funds left over from GO bonds are relatively simple procedures. A municipal note of small face value may be difficult to sell. Commercial banks often collect groups of these notes for a fee and then resell them to individual investors. Such fees should be computed into the capital cost of a project. Although direct bank borrowing is rare, it does take place. Interest rates or such funds are high, however, it is a means of raising small amounts of capital quickly. Bank loans are usually used to finance front-end planning and some of the construction costs of expensive facilities.

6.5.2 Long-Term Options

There are two main long-term options available to municipal governments: revenue bonds and general obligation (GO) bonds.

Municipal Revenue bonds are long-term, tax exempt obligations issued directly to municipalities, authorities, or semi-public agencies for amounts usually over $1 million. Typically, a revenue bond is negotiated rather than competitively underwritten. Negotiation means the city meets with one underwriter to determine what profit the underwriter will make. Interest rates for negotiated bonds are usually higher than competitive rates; however, the investment banker incurs the cost of providing free advice and the preparation of the revenue bond circular and official statement. The city may also find it necessary to hire a consultant to confirm the investment banker's estimates of costs and revenues.

Municipal Revenue bonds do not require voter approval. This may reduce delays and costs that result from citizen vote. Revenue bonds are not restricted by municipal debt ceilings, because they are not a function of the tax base. These bonds require detailed disclosure of the technical basis, economical viability, administration, and financing of the project. The reports and summaries required are expensive to prepare and the bonds do have high fixed administrative and transaction costs. As noted previously, revenue bonds have higher interest rates than GO bonds-usually 30 to 45 basis points (a point equals 1/100 of a percent). Interest rates are higher due to higher risk involved by investors. This risk can be lowered, however, through contractual obligations, so that revenue bonds take on the risk characteristics and interest rate of GO bonds. Revenue bonds may only be used for a single project. This type of bond is usually used when a major project will generate enough revenue to operate and maintain the facility, as well as pay the interest and principal on the debt.

General Obligation bonds - are long term, tax-exempt obligations secured by the full-faith-and-credit of a political jurisdiction which has the ability to levy taxes. The capital market determines the creditworthiness of a local government and does not specifically evaluate the risks of a particular project. Typical GO bonds are offered competitively for sale to bidders. The bidder offering the lowest net interest cost to the city wins the right to place the bonds with its customers.

Voter approval is required to offer a GO bond. GO bonds usually have lower interest rates than revenue issues. The lower interest rates is a result of the fact that the city guarantees the bond by its tax-collecting capacity. The minimum offering size for GO bonds is approximately $500,000.

If a project costs less than $500,000, several projects may be grouped together under a single offering, as long as voter approval is reached on each project.

It should be noted that a municipality may require the services of financial consultants, investment bankers, and bond counsels. All of these professionals offer services which allow a municipality to best understand the comparative costs of various funding practices. The cost of these services should be included in the overall capital costs of a project.

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